

MOON SHOT

GETTING THERE

FIRST ON THE MOON

SPLASHDOWN

'THAT'S ONE SMALL STEP FOR a man, one giant leap for Mankind,' Neil Armstrong announced to an audience of millions, glued to their television sets the world over, as he cautiously made the first footprint on the Moon.

History was made on 20 July 1969, four days after a mighty Saturn V rocket, over 110 metres tall, thundered skyward from its launch pad at Cape Canaveral, in Florida, USA.

Right on top of the rocket was the spacecraft, *Apollo 11*, which would be detached from the rocket to head for the Moon. Strapped into its cramped crew compartment, the command module, were astronauts Neil Armstrong, Edwin 'Buzz' Aldrin and Michael Collins – two of whom would be the first men ever to attempt to land upon another world.

Destination Moon

The rocket itself was made up of several 'stages'. These are separate sections designed to be jettisoned in space after each has fulfilled its

function in providing the necessary boost.

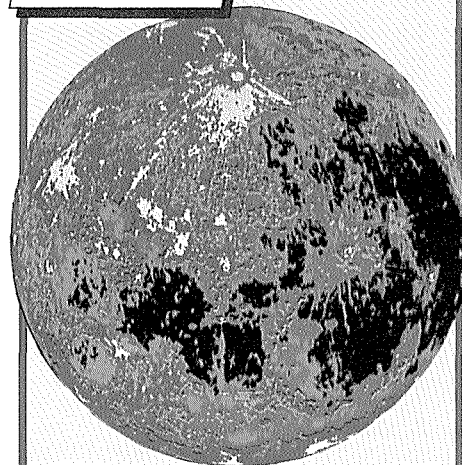
At 9.32 a.m. on Wednesday, 16 July 1969, 15 tonnes of fuel and liquid oxygen were burned each second as the rocket lifted off. Two and a half minutes later and 61 km up, the first stage separated and fell back to Earth. This had carried the vast quantity of fuel for the massive initial thrust.

At a speed of 9,978 km/h, the second stage fired, carrying the rest of the rocket a further 124 km higher, reaching a speed of 24,940 km/h within six and a half minutes.

Stage two now fell away, and the stage three rockets fired, carrying the spacecraft into orbit around the Earth. Later, the rockets fired again, this time setting *Apollo* on course to the Moon.

Astronaut Schmitt examines a giant boulder on the last Moon mission. It was probably one of many thrown up by the impact of a meteorite millions of years ago. Harrison Schmitt was the first real scientist to land on the Moon.

PROFILE THE MOON



Dr Fred Espenak/SPL

The Moon shows a vivid face in a false-coloured telescope photograph. Earth's only natural satellite, the Moon is lifeless, airless and rocky.

Diameter 3,476 km

Distance from Earth

furthest 406,600 km

nearest 356,300 km

average 384,000 km

Temperature

maximum 101°C

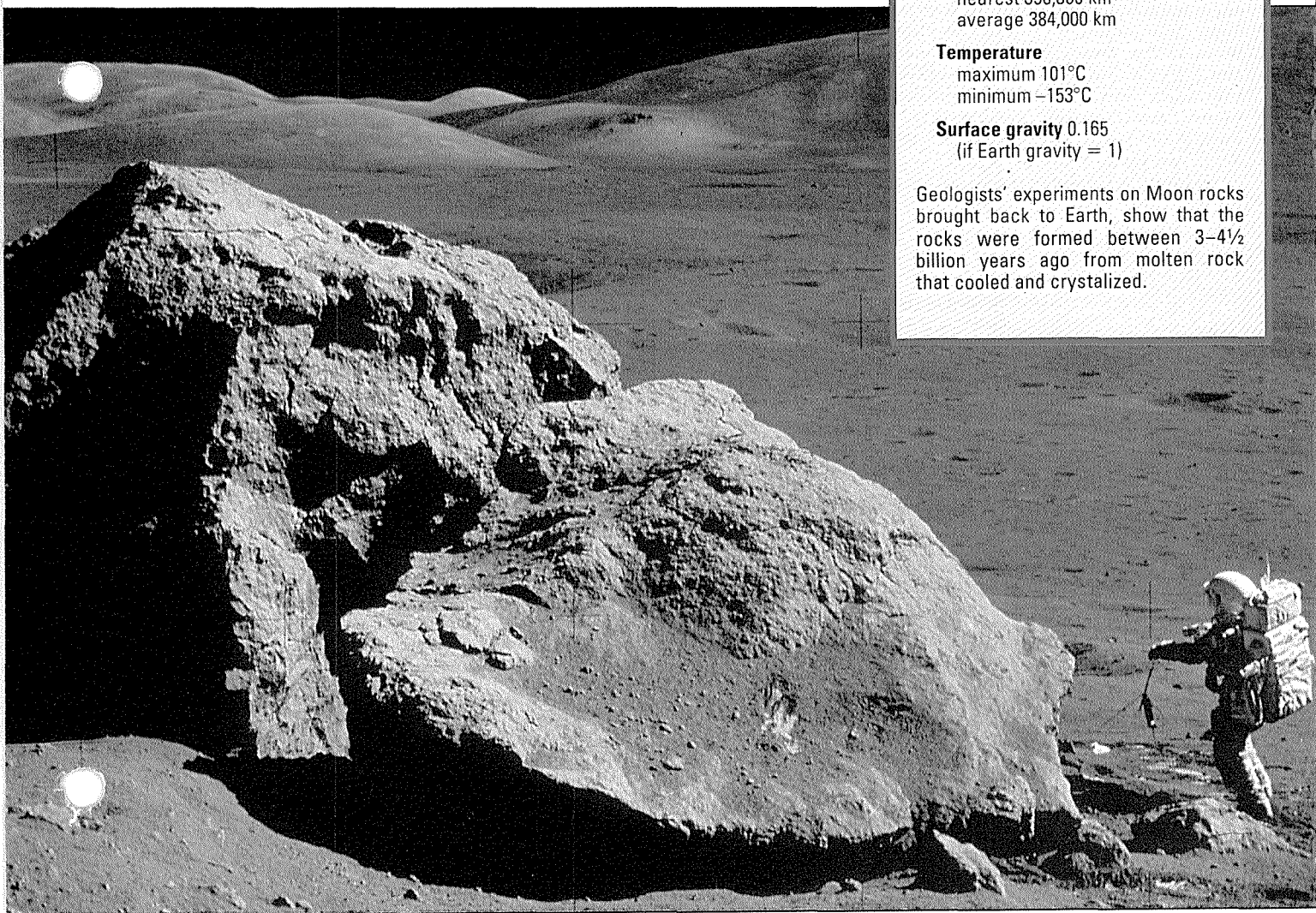
minimum -153°C

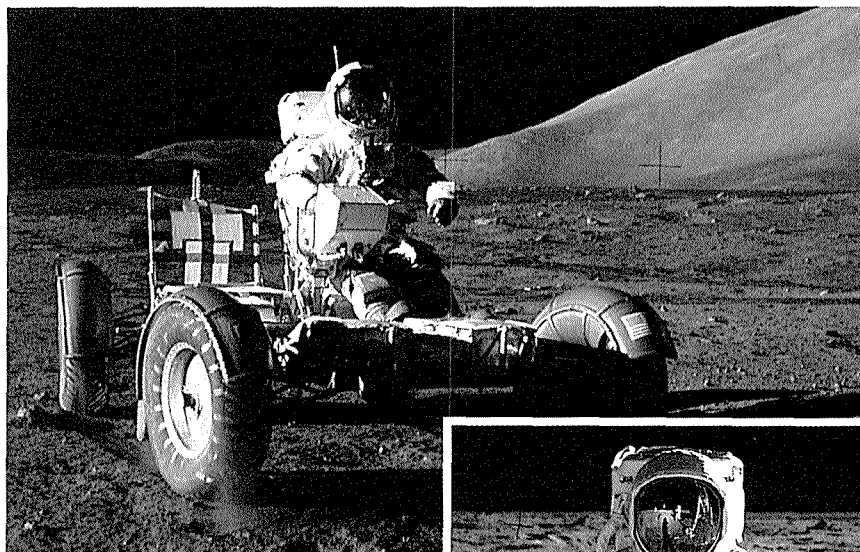
Surface gravity 0.165

(if Earth gravity = 1)

Geologists' experiments on Moon rocks brought back to Earth, show that the rocks were formed between 3-4½ billion years ago from molten rock that cooled and crystallized.

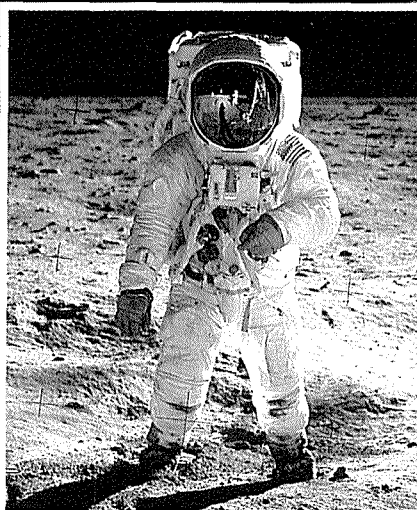
NASA





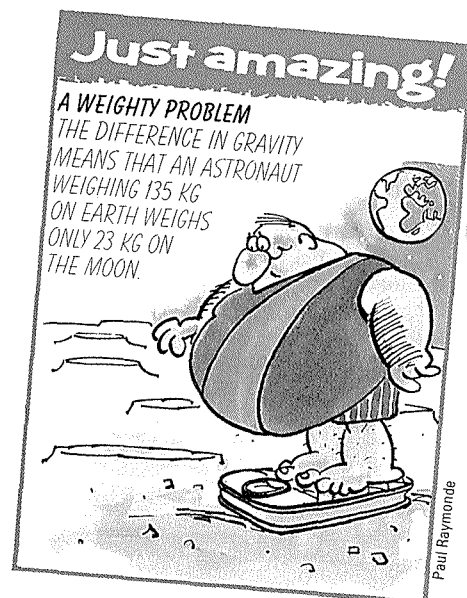
A Lunar Rover was used by later Apollo missions to taxi the astronauts on the Moon. It could also receive and send messages.

The Moonsuit is a mini home for the astronaut. It provides air, the right temperature and protects him from flying meteorites.



Apollo 11 came away from the lunar module – still housed within stage three of the rocket – and turned around 180°. The command module now docked with the lunar module.

Stage three of the rocket fell away. In orbit around the Moon, two of the astronauts, Armstrong and Aldrin, crawled into the lunar module via a tunnel.

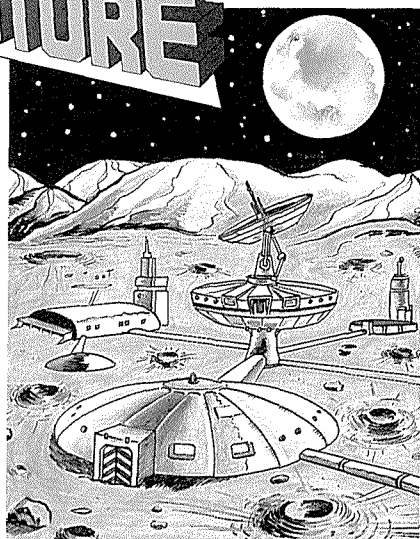


Nicknamed 'Eagle', the lunar module now separated from its docking with the command and service modules and began its descent to the Moon.

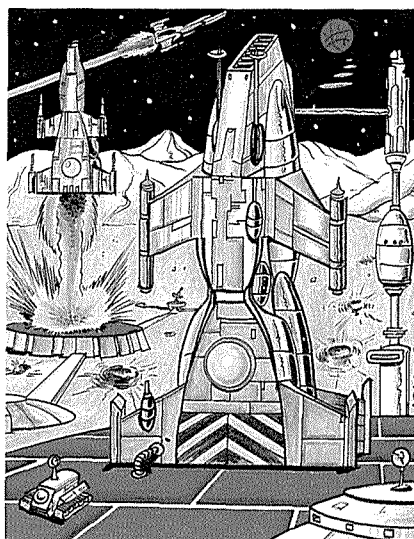
The two astronauts spent 22 hours on the Moon. They collected over 20 kg of Moon rock and soil which, at first, were handled with extreme care in a specially sealed laboratory.

To return from the Moon, the astronauts took off from the top half of the lunar module, the lower half acting as a launch pad. After re-docking with the command module, they crawled back, leaving the lunar module in space. Just before re-entry, the faithful service module was finally ditched. The command module made its solitary return home to splashdown and a jubilant welcome.

INTO THE FUTURE



▲ Living on the Moon is a real possibility. At first, a few people could live there permanently, as water and oxygen can be made from the rocks and soil.



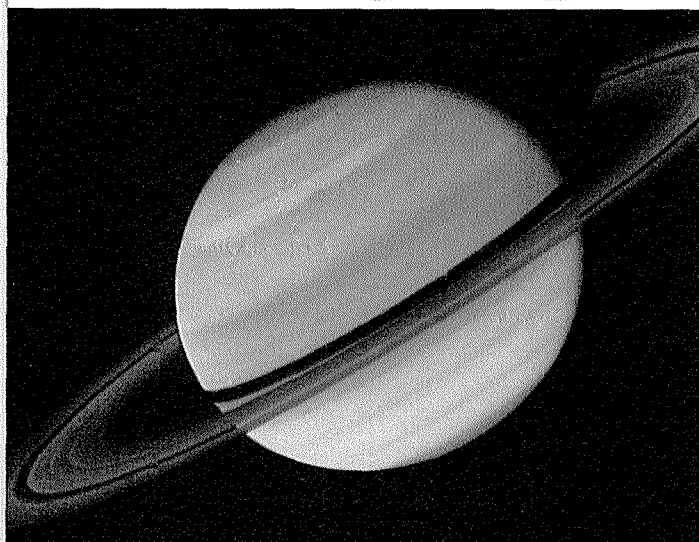
▲ Later, large spacecraft built from metals extracted from lunar rocks could be launched to provide two-way travel between Moon and Earth.



▲ In time, the Moon could accommodate more and more people. Children born there would consider the Moon their true home, returning to Earth only for visits.

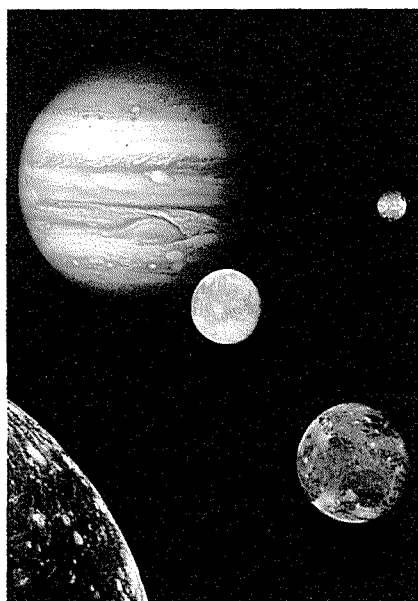
THE OUTER PLANETS

 GAS GIANTS  RINGS  MOONS



Saturn and its magnificent rings, photographed from the Voyager 1 spacecraft. Extra colour has been added to show up detail. Ammonia gas in the depths of the atmosphere appears as orange, while the bluish regions may be floating ammonia crystals. The rings of Saturn proved to be made up of thousands of 'ringlets' when seen close up from Voyager.

IMAGINE A SWIRLING STORM wider than the Earth that has been raging for over two centuries. Or a moon peppered with lakes of lava and huge, erupting volcanoes. Or a planet that seems to have been rammed by another world.



JPL, California

The moons of Jupiter show up starkly against their mother planet. (From the top) Io, Europa, Ganymede and Callisto are the four largest of Jupiter's 16 moons. All four satellites could fit snugly inside the Great Red Spot: end-to-end they measure 15,000 km, while the Spot is over 25,000 km long.

These are just some of the astounding discoveries scientists have made in the realm of the outer planets. Beyond the orbit of Mars, at many times the Earth's distance from the Sun, lie the planets Jupiter, Saturn, Uranus, Neptune and Pluto. All, except for tiny Pluto, are much bigger than our world.

The icy giants

As we move further from the Sun, we leave behind the warm, rocky worlds of the solar system, and enter a place where the Sun's heat and light is not so strong. There, the space is cold and the planets are frozen. This is the realm of the icy giants.

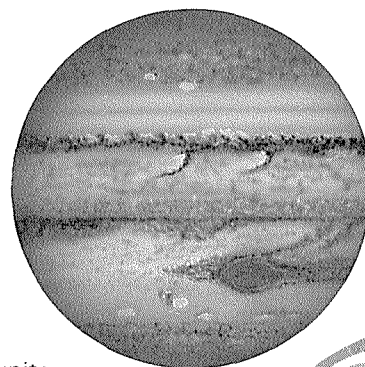
PROFILE Planet Data

Skirting the outer limits of our solar system, the five outer planets offer a cold, inhospitable and alien environment where the days merge into years and the years into centuries.

	Jupiter	Saturn	Uranus	Neptune	Pluto
Distance from Sun (million km)	778	1,427	2,870	4,497	5,900
Diameter (km)	142,796	120,000	50,800	48,600	2,250
Length of day	9 h 50 m	10 h 13 m	17 h 14 m	18 h 24 m	6 h 23 m
Length of year (in Earth years)	11.9	29.5	84.0	164.8	247.7
Temperature (cloudtops)	-150°C	-180°C	-210°C	-220°C	-240°C
Number of moons	16	21	15	8	1

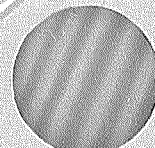
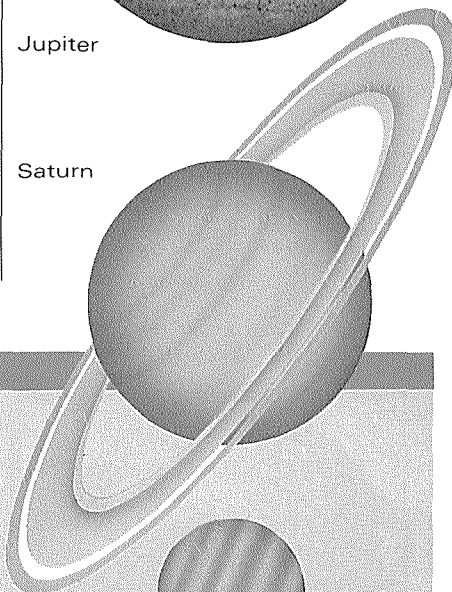
Jupiter, for instance, is so huge it could swallow up 1,300 Earths. Like its giant neighbours, Jupiter has no visible solid surface. All that can be seen from space is the top of its whirling, multi-coloured atmosphere of hydrogen, helium, methane and ammonia. Thousands of kilometres thick, this huge gassy blanket is thought to hide an even deeper, syrupy ocean of liquid hydrogen. Only at the planet's very centre is there perhaps a hard core of rock and metal, not much bigger than the Earth.

Best known of Jupiter's features is its Great Red Spot. An enormous oval whirlpool of gas with winds howling around its edge at 360 km/h, the Spot measures up to 25,000 km in length. No-one knows when it first formed. Jupiter and its family of 16 moons are like a miniature solar system. So, too, is Saturn, the next planet out, at almost twice Jupiter's distance from the Sun.

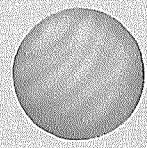


Jupiter

Saturn



Uranus



Neptune

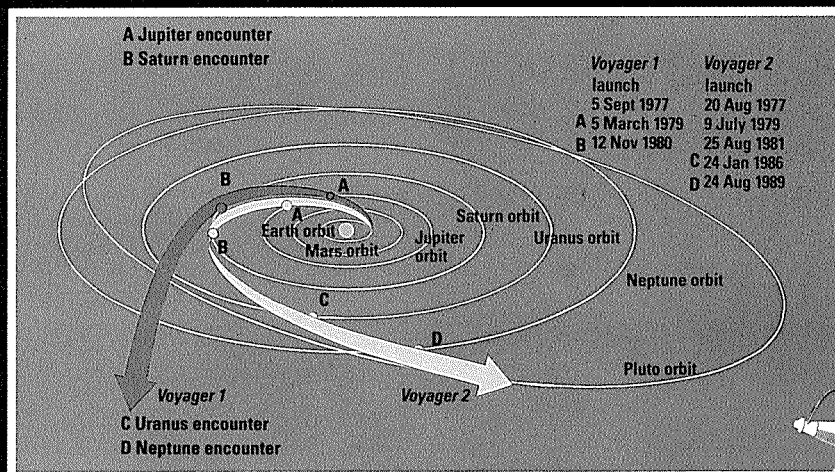


Pluto

Mark Franklin

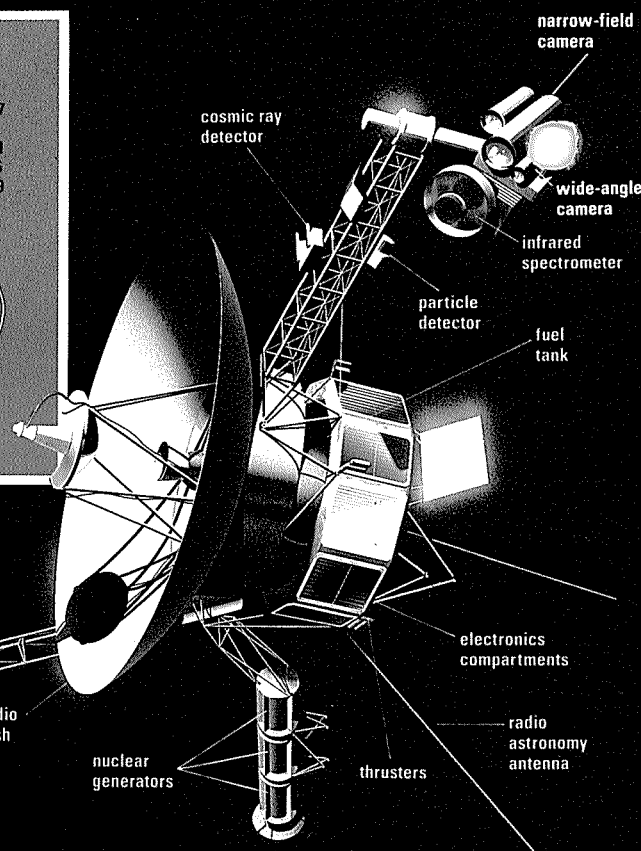


THE ORBITS OF VOYAGERS 1 AND 2



Our knowledge of the outer planets has been revolutionized by the epic journeys of the two *Voyager* spacecraft. Both craft used the gravity fields of the planets they encountered to boost them on their way across the solar system. *Voyager 1*,

launched in 1977, reached Jupiter after 18 months' travel. The planet swung the craft round and flung it towards Saturn. *Voyager 2* is now on its way to an encounter with Neptune.



At least 21 satellites move in orbit around Saturn. The biggest is Titan, whose surface is forever veiled by a thick red smog. But what makes Saturn spectacular is its fabulous collection of rings. Although from far away they seem solid, the rings actually consist of countless numbers of small chunks of rock and

ice, wheeling around Saturn like tiny moons.

Until recently, Saturn was thought to be the only ringed member of the Sun's kingdom. But scientists have recently learned that Jupiter, Uranus and Neptune are surrounded by rings.

Eleven narrow rings, blacker than charcoal, encircle the mysterious planet Uranus. So, too, do 15 known moons – among them little Miranda, with its amazing jumbled-up surface. Miranda may have been blasted apart on at least five separate occasions, when other objects crashed into it. But each time the fragments of the little moon stubbornly reassembled themselves.

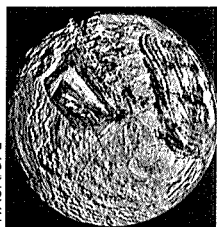
When worlds collide

Not only Miranda may have suffered collisions in the remote past. For many years, astronomers have wondered why Uranus, unlike every other planet, spins around on its side. The most popular explanation is that, billions of years ago, another object – maybe an Earth-sized planet – blundered into it at high speed, completely bowling it over.

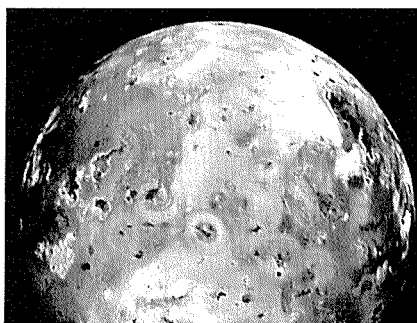
Still further out, another ancient catastrophe may have occurred in the neighbourhood of Neptune. One of Neptune's moons, Triton, revolves around its parent planet the 'wrong' way. Another Neptunian moon, tiny Nereid, moves along a path that is incredibly stretched-out. Not only this, but Pluto, the outermost planet, is not always the

furthest away. Its orbit is so elongated that, for 20 years in every 250, it skips inside Neptune's orbit.

All these strange orbits led some scientists to think that Pluto was once a moon of Neptune, and that there is an even bigger planet, beyond even Pluto, that has pulled Pluto and Triton out of their natural orbits. Planet X, if it exists, would be so far out from the Sun that it would only come into view every thousand years or so. There has been no sign of it as yet, but *Pioneers 10* and *11* are shortly going to leave the solar system. On their way, they may stumble upon the tenth planet!



Miranda, one of 15 known moons of Uranus, is scarred by huge ridges and craters. One canyon has walls 15 km high – twice the height of Mount Everest.

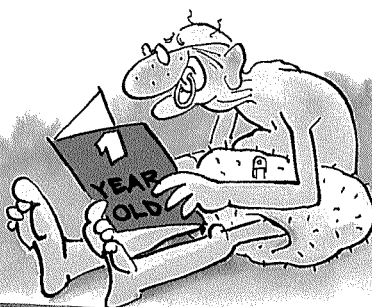


Io, which is slightly larger than our Moon, is torn by ceaseless volcanic activity, caused by the stresses of Jupiter's enormous gravity. Its entire surface is covered with reddish sulphur compounds.

Just amazing!

YEAR IN A LIFE

BIRTHDAY CANDLES WOULDN'T SELL VERY WELL ON PLUTO, SINCE BIRTHDAYS WOULD BE FEW AND FAR BETWEEN. THE PLANET TAKES SO LONG TO TRAVEL AROUND THE SUN THAT EACH OF ITS 'YEARS' LASTS OVER 247 EARTH YEARS.



Paul Raymond



MARS

MAN'S NEXT BASE

- ☐ LIFE ON MARS?
- ☐ GIANT VOLCANOES
- ☐ TARGET PHOBOS

SLOWED BY THREE GIANT parachutes, each as wide as a football field, the first manned craft to Mars descends through the planet's thin atmosphere. A few hundred metres above the ground, its retro-rockets fire, kicking up some of the rust-coloured dust that covers the surface. Seconds later, the capsule, with its eight-member crew, gently touches down on the mysterious 'Red Planet'.

Sometime in the 21st century, this historic event really is going to happen. Even now, scientists in the United States and CIS are urging their governments to co-operate in a manned mission.

Beyond the Moon, Mars is the next easiest world for humans to visit and explore. Not only that, but it may be an ideal place to set up a permanent base for scientific studies and for further investigation of the solar system.

Survival

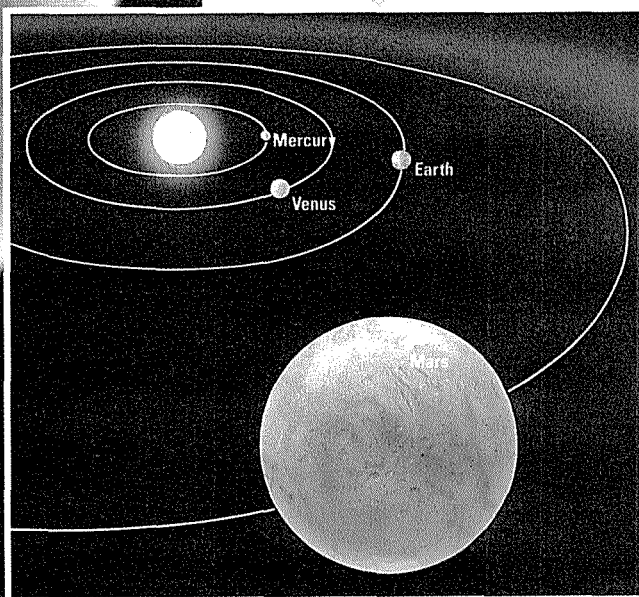
Apart from the Earth, Mars is the friendliest world we know. Its thin carbon dioxide atmosphere is harmless (though not life-supporting), and, with an average surface temperature of minus 23°C, Mars is generally no cooler than the Antarctic in winter.

Even so, the first explorers will need plenty of protection from Martian conditions. Spacesuits will be vital because the atmosphere is so thin that, by Earth standards, it is a near vacuum.

There is no chance that Mars explorers could survive in it. Even if it consisted of pure oxygen, no-one could breathe Mars' air. Our bodies require a much greater pressure of

Mars is the fourth closest planet to the Sun. The most Earth-like of the planets, it could become Man's first colony in space in the next century.

JPL/NASA



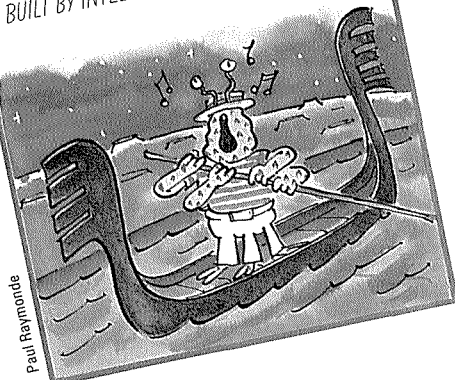
Pavel Kostal



Just amazing!

MARTIANS AT WORK!

PERCIVAL LOWELL, THE AMERICAN ASTRONOMER, CAUSED A SENSATION LAST CENTURY WITH HIS CLAIM THAT MARS WAS CRISS-CROSSED BY A NETWORK OF CANALS BUILT BY INTELLIGENT BEINGS.



gas to breathe. One problem is that, as the atmospheric pressure goes down, so does the boiling point of a liquid. On a high mountain on Earth, water boils at only 70°C. On Mars, blood at body temperature would begin to boil almost immediately.

But even in their cumbersome spacesuits, the explorers will find that they can move around just as easily as they can on Earth. This is because Mars' surface gravity is much lower. You would weigh only 38 per cent of what you do on Earth. A future Mars Olympics would quickly set its own records for athletics.

On Mars' surface, everything is

MARS MISSIONS

Launched	Nation	Probe	Achievements
1964 28 November	USA	Mariner 4	Fly-by mission. Sent back pictures of Martian surface and data on its atmosphere.
1965 18 July	USSR	Zond 3	Successful communication test with spacecraft crossing Mars orbit.
1969 25 February	USA	Mariner 6	Fly-by pictures of surface showed Moon-like craters.
1969 27 March	USA	Mariner 7	Fly-by mission. Sent back pictures of surface.
1971 30 May	USA	Mariner 9	Orbited Mars and transmitted hundreds of photographs of Mars and its satellites, together with much other data.
1973 25 July	USSR	Mars 5	Orbited Mars and returned photographs of surface and data on atmosphere.
1973 5 August	USSR	Mars 6	Returned atmospheric data, but contact with landing craft lost just before touchdown.
1975 20 August	USA	Viking 1	First soft landing on surface and first pictures from surface.
1975 9 September	USA	Viking 2	Soft landing. Pictures transmitted from the surface.
1988 7 and 12 July	USSR	Phobos	Two spacecraft sent to study Mars and land on its moon, Phobos. Contact with one craft lost <i>en route</i> and the other after arrival at Mars, March 1989.

Two US Viking spacecraft were put into Mars orbit in 1976. They ejected lander capsules, which parachuted to the surface to test the soil and atmosphere and send back photographs. The Viking 2 view shown here was beamed back via the radio dish antenna (top).

red. Even the sky is tinged pink, especially low down, near the horizon. This is because Mars is covered with fine red dust, so light that it hangs in the air.

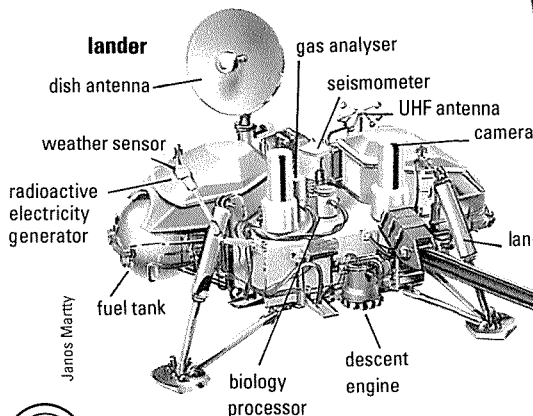
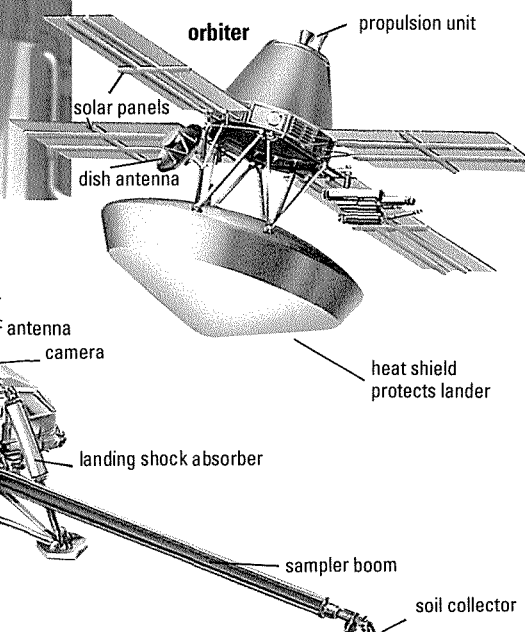
The red colour is caused by iron. Just as rust is red, so the soils of Mars, with a significant iron content, are red. This same soil covers the entire planet.

A windy wasteland

Mars explorers will have to become used to the red wasteland. The surface is boulder strewn, but across this blows a thin wind, which is capable, over the centuries, of wearing down the rocks. And because the air is thin, the wind can blow much faster (in the same way that water flows faster than oil).

So particles of sand can be picked up and whisked high into the air. Even from Earth, observers with backyard telescopes can gaze at huge dust storms, sometimes covering the whole planet for weeks at a time.

Dust could be a major irritation for Martian explorers as it could get everywhere. Things will have to be specially dustproofed, because the dust will undoubtedly find its way into the living quarters on people's



PROFILE

MARS COMPARED WITH THE EARTH

On Mars, a day lasts about the same time as a day on Earth. But, in most other ways, Mars is quite different to our planet.

Measurement	Mars	Earth
Diameter at equator	6,786 km	12,756 km
Distance from Sun (mean)	227 million km	149 million km
Mass	0.107 Earth mass	1 Earth mass
Volume	0.15 Earth volume	1 Earth volume
Density	3.9 g/cubic cm	5.5 g/cubic cm
Gravity at surface	0.38 Earth gravity	1 Earth gravity
Time to rotate on axis	24 hr 37 min 23 sec	23 hr 56 min 4 sec
Time to orbit the Sun	686.98 Earth days	365.26 Earth days
Number of moons	2	1

NASA

boots, just as lunar soil did on the *Apollo* missions.

Imagine that you are in the first manned spaceship to land on Mars. Out of the window you would probably see sand dunes caused by the wind-blown dust. Two American Viking probes sent back pictures of just such a view in 1976.



Martian landscapes

You might be lucky enough to be able to explore the amazing surface of Mars. There are volcanoes, including the largest known in the solar system, Olympus Mons. No-

one knows if they are still active. There are chasms, the largest of which, the Valles Marineris, would dwarf the Grand Canyon.

These chasms seem likely to hold Mars' most fantastic secret — for they were apparently cut by vast rivers of floodwater. Yet Mars is now drier than any Earth desert. One of the prime tasks of the early explorers will be to discover if reserves of frozen water still exist deep below the Martian surface, as most experts believe. One thing that the explorers won't find, however, is the famous canals. The long,

The flat Argyre crater and its surrounding mountains were formed when a huge meteorite smashed into the surface.

straight features seen by astronomers from Earth are now thought to have been an illusion. No real features on Mars tie in with their supposed positions, so the idea of intelligent Martians is now regarded as science fiction.

A trip to one of the poles would take you to the polar caps. There is an icy cap at each pole, but they are different from each other. The northern cap is probably water ice, like Earth's, but the southern one is more likely to be frozen carbon dioxide — dry ice. Both increase in size in winter, then shrink as summer returns. This constant freezing and melting has created weird ice cliffs. They may become one of the sights of the solar system.

Mars has seasons just like Earth, but the year is about twice as long as ours. One thing that explorers will find familiar on Mars is the length of the day. It is very similar to our own, 24 hours and 37 minutes long, providing an almost ideal cycle of light and dark for both humans and plants grown for food. But before people go to Mars, we must first learn more about the planet.



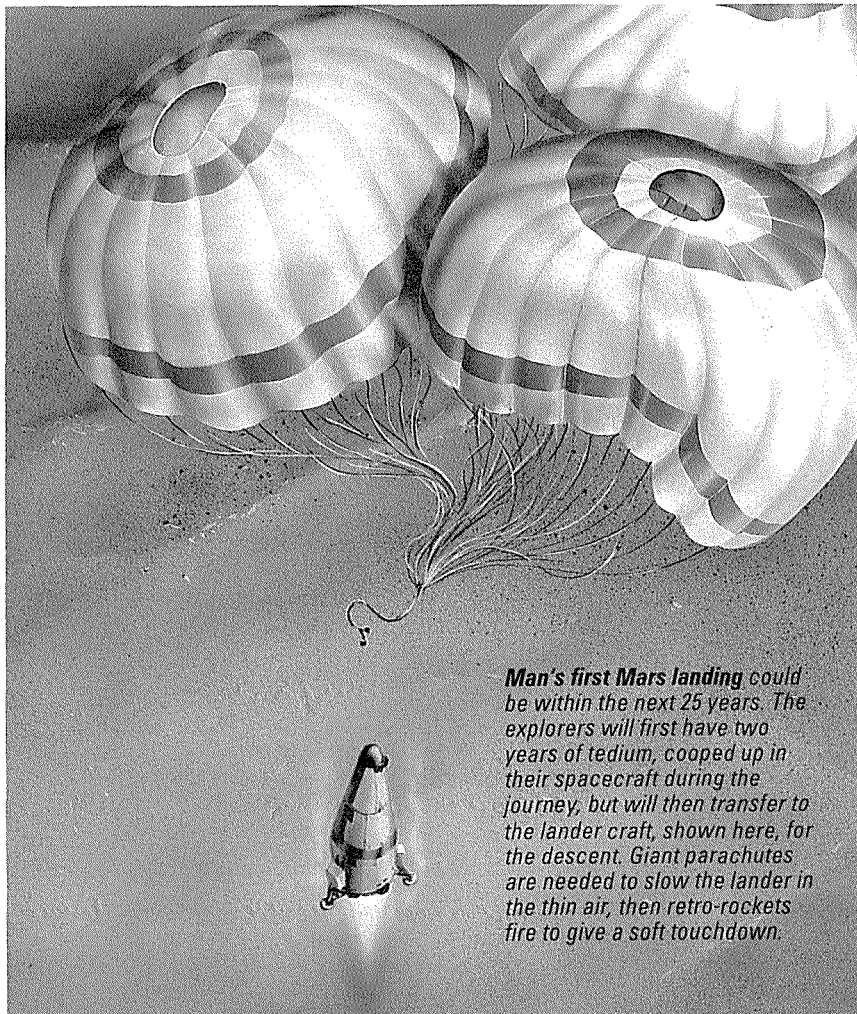
Target: Phobos

In 1988 two probes were launched by the former Soviet Union with the intention of landing on Phobos, the larger of the two moons of Mars. It is thought that Phobos could be an important source of raw materials and water for astronauts next century. Contact with both probes was lost before landing on Phobos so they were unsuccessful, but several other Mars probes are already planned.



Mars Observer

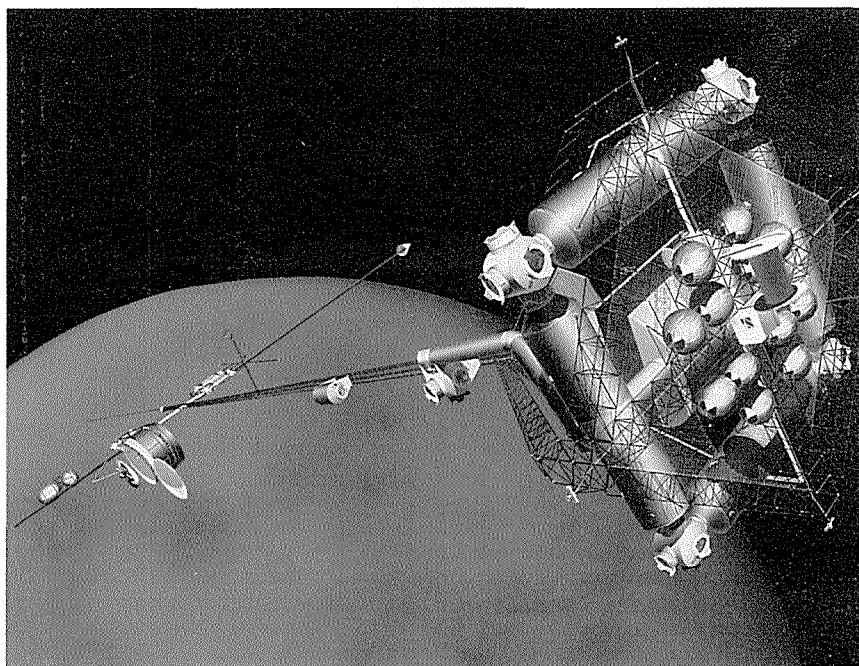
In August 1993, after an 11-month trip, NASA's Mars Explorer spacecraft will go into orbit around the red planet, circling from pole to pole at an altitude of less than 400 km. The Mars



Man's first Mars landing could be within the next 25 years. The explorers will first have two years of tedium, cooped up in their spacecraft during the journey, but will then transfer to the lander craft, shown here, for the descent. Giant parachutes are needed to slow the lander in the thin air, then retro-rockets fire to give a soft touchdown.

Mike Saunders





A US space station like this may be put into orbit around Mars. The station will be used as a base for mining and manufacturing activities on the Martian moon Phobos and for exploration voyages to the surface on Mars.

Observer craft will photograph the planet's surface features, study the composition of its rocks and follow its weather patterns throughout one complete Martian year, 687 Earth days. It is expected to find out more about Mars than all previous missions put together, and help pave the way for the first manned bases there.

While Mars Observer is still operating, a CIS mission called Mars 94 is due to land several small scientific stations on the planet in late 1995, and Mars Observer will relay data from these stations to Earth. A second CIS mission, Mars 96, will carry automatic Mars rovers and release balloons into the Martian atmosphere to study its weather.

Engineers at NASA's Jet Propulsion Laboratory in Pasadena have tested a Mars rover of their own, called Rocky, that could be driven over the surface of Mars by remote control from Earth, sending back pictures as it goes. Before humans ever leave for Mars, therefore, we will know what it is like to roam around on the surface. Rocky could be launched in 1996 as part of the Mars Environmental Survey (MESUR) Pathfinder mission.



Martian explorers

When will the first humans set foot on Mars? And who will they be? One possibility is that, some time next century, the CIS and the USA will work together to send a manned

spacecraft to Mars. The Mars ship would be assembled, in Earth orbit, from sections launched by the Space Shuttle. Then, with the crew on board, its engines would be fired to put it on to a curving path away from the Sun.

In a mission lasting two to three years, the astronauts would spend about six months on the Martian surface.

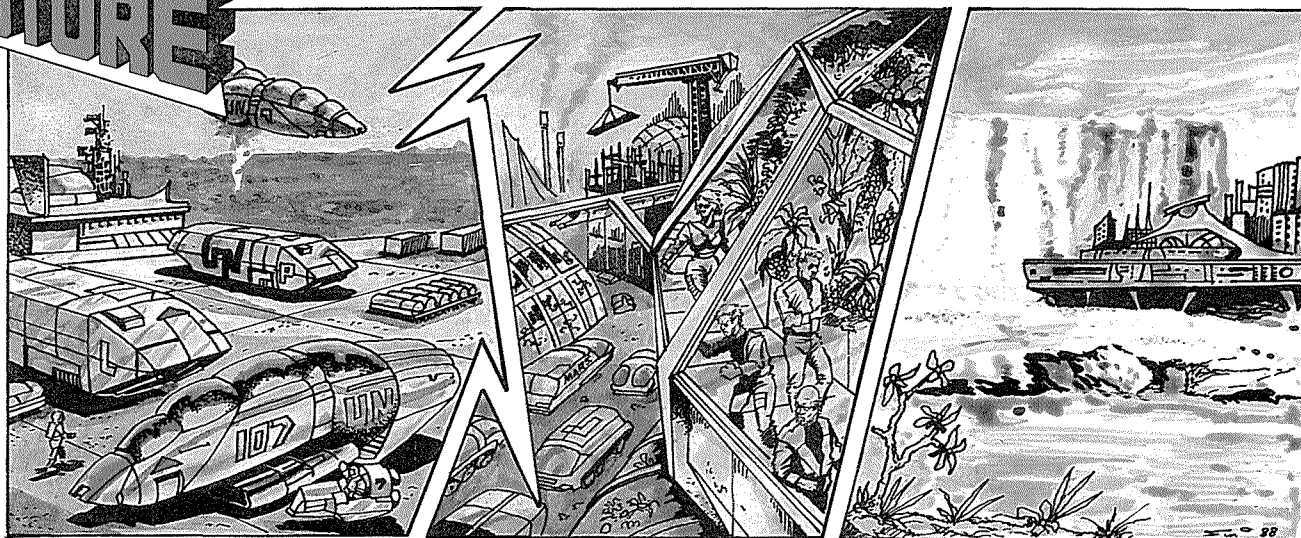
This means that the astronauts will have to create a true base, totally self-sufficient. They must be prepared for Martian extremes – the cold, the low pressure, the dust storms and the lack of protection from the Sun's radiation.

The best protection against radiation is to dig in. A metre or two of soil on top of the living quarters would be sufficient. NASA scientists are investigating various ways of doing this. One method would be to bury the quarters underground.

During their stay, those first explorers might travel many kilometres from their base camp in a special vehicle. And there are even plans for a special unmanned aircraft with huge wings and an enormous propeller. It could drone high over the fantastic canyons and mighty volcanoes, taking photographs. Meanwhile, the scientists would collect thousands of rock and soil specimens, drill for underground water, test the atmosphere, and search for traces of life.

INTO THE FUTURE

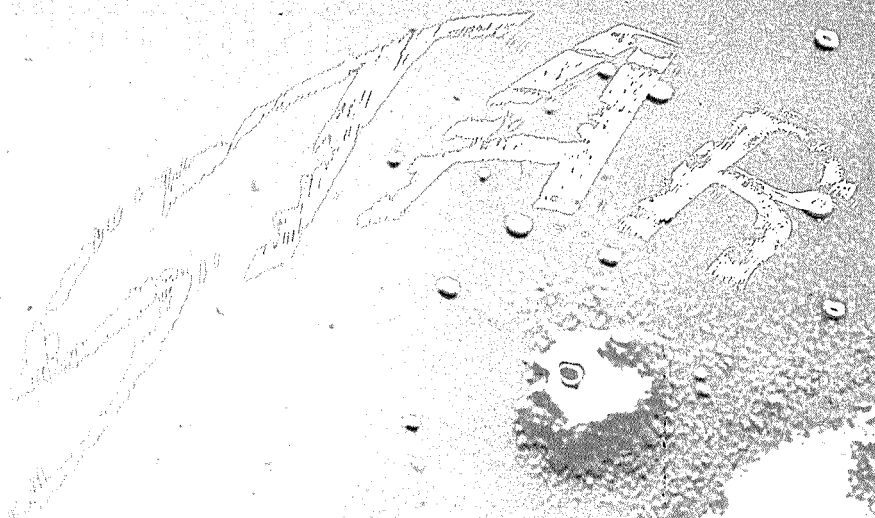
OUTPOST ON THE RED PLANET



▲ A regular spacebus service could ferry people from giant transporter spacecraft, linking Earth and Mars, to a permanent base on the Martian surface.

▲ Factories could make fuel, fertilizer, building materials and even oxygen from the Martian rocks. Food could be grown in giant greenhouses.

▲ Plants cultivated around the ice caps would absorb heat from the Sun. The ice would melt to form seas and, in time, Mars might become more like Earth.



The Orion nebula, a cloud of gas and dust in which new stars are born. Colours in this picture are false. They have been applied to a black-and-white photograph to show clearly the boundaries between different shades of grey. Inside the cloud, giant stars form in a spectacular way, as illustrated below.

ON 20 FEBRUARY, 1987 AN event took place that set astronomers around the world buzzing with excitement. A star had just been seen to explode in a nearby galaxy visible from the southern hemisphere. It was the closest stellar blow-out, or 'supernova', to have occurred for nearly 400 years.

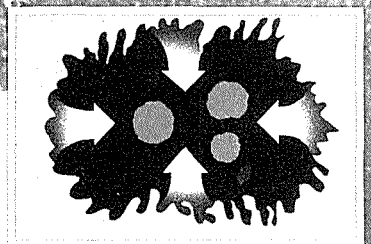
Stars rarely show any signs of change, even over many human lifetimes. A star like the Sun, for instance, can keep on shining more or less steadily for thousands of millions of years. Even so, stars cannot live forever. They are born, they develop and mature, and, eventually, they die — sometimes very spectacularly indeed.

Drifting around our galaxy are vast clouds of gas and dust. The material in these clouds — mainly hydrogen gas — is spread out incredibly thinly. Yet over many mil-

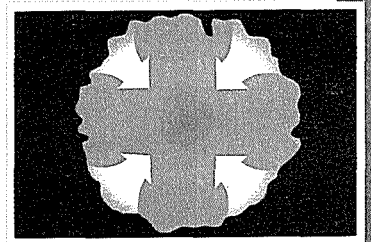
lions of years, the gravity-pull of such a great billowing object may be enough to draw together the gas and dust particles into thicker, ball-shaped clumps.

These clumps, or globules, then shrink further, becoming denser and hotter. Finally, the hydrogen gas at the heart of a globule reaches a temperature of over 15 million degrees C. Then it begins to pour out light and heat by nuclear fusion — the same process that powers a hydrogen bomb. A new star is born.

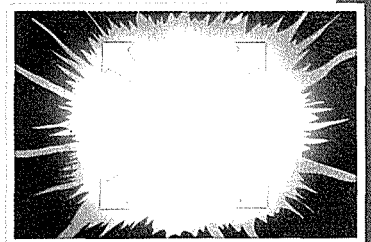
What happens next depends on the mass of the infant star. If this is especially high, then the star's core is squeezed very hard and the hydrogen gas there 'fuses' into the next heavier element, helium, at a tremendous rate. Despite starting off with a huge supply of hydrogen, a heavyweight star squanders its main fusion fuel recklessly. Within just a few million years, the stellar giant may start to use up other substances, heavier than hydrogen.



Initial stages of star formation: a globule contracts into a protostar.

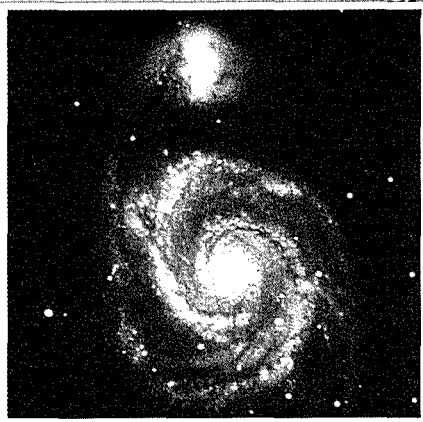


Protostar contracts, heating up and becoming denser.



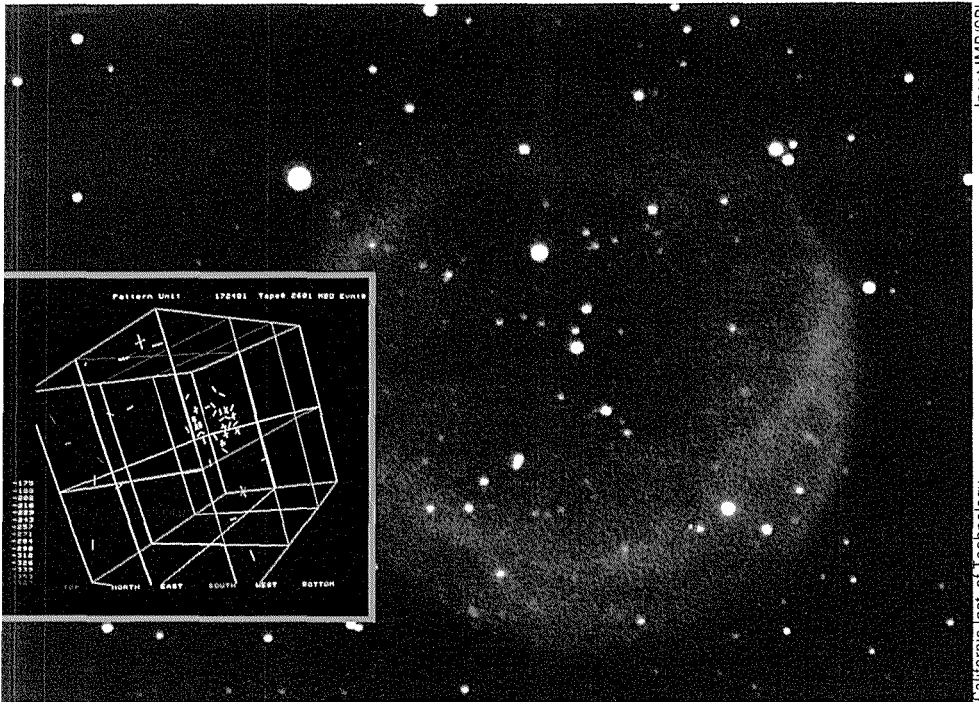
A supernova explosion: the outer layers of the star are blown off.

Ronald Royce/SPL, Dr. Fred Espenak/SPL



The Whirlpool galaxy has a clearly defined spiral form. Light from this multi-billion star collection takes 20 million years to reach Earth.





Inset IMB/SPL
California Inst. of Technology

SPL

Aquila planetary nebula – a spherical cloud of dust and gas left over from the death of a star. The computer display (inset) shows a neutrino particle received in 1987 from the supernova explosion of a supergiant star.

But these fuels, such as helium and carbon, are much poorer sources of light and heat.

Eventually, even the most massive of stars loses its ability to create fresh energy. Then the star's core can no longer support the enormous weight of the surrounding layers. In the wink of an eye, the dead core collapses while, at the same time, the star's outer parts are hurled into space at enormous speed. Even from far away, such a supernova blast is impressive.

Unlike the real stellar heavyweights, most stars, including our own Sun, will never blow themselves to bits. Even so, they can undergo surprising changes during the course of their life.

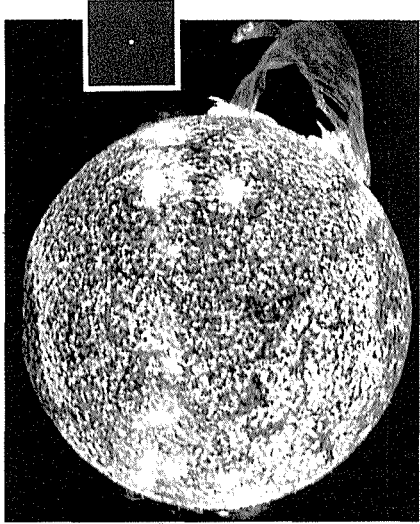
About five billion years from now, most of the hydrogen at the centre of the Sun will have been used up. For a while, the solar core will stop making energy and will shrink, becoming steadily hotter. At the same time, the outer layers of the Sun will slowly balloon out. As its surface swells and cools, the Sun will turn into a monstrous red giant.

Eventually, the Sun's shrinking core will become hot enough for helium to start fusing into carbon. In the millions of years that follow this, the bloated outer parts of the Sun will rise and fall like a great lung breathing in and out. Each time this

happens, some of the loosely-held gas from the upper layers will leak away into space. Bit by bit, the Sun will shed all of its giant atmosphere. The lost gas may collect as an enormous glowing ring or shell, known as a planetary nebula.

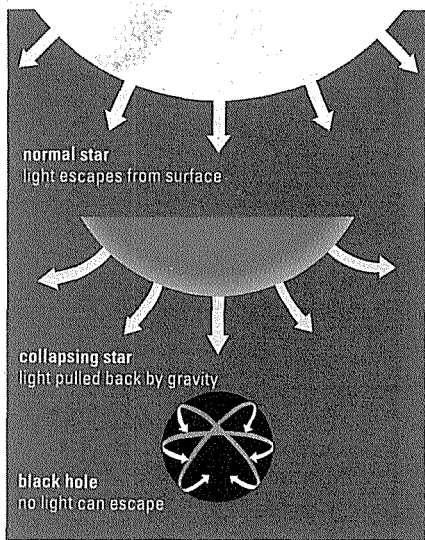
All that will be left of the Sun is its super-hot exposed core. No bigger than Earth and with a surface temperature of about 100,000 degrees C, the Sun will have turned into a white dwarf star.

Sometimes violently, sometimes gently, all stars throw some matter back into space. Over long periods of time, this cast-off material gathers up into new clouds of gas and dust from which future generations of stars will form.



A solar flare from Earth's closest star, the Sun. This spectacular gas eruption extended more than 588,000 km from the surface. The Earth is shown at the same scale for comparison.

THE BLACK HOLE ENIGMA



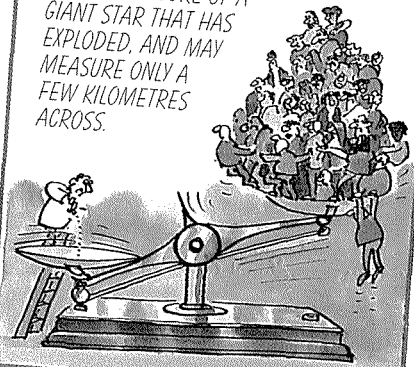
USAF/Berry Fallon Design

When a giant star blows up, most of its contents are thrown violently out into space. But the remaining lifeless core quickly shrinks. It may collapse until it is a solid ball of particles called neutrons. In extreme cases, the dead core becomes so compact that it forms what astronomers call a black hole. Its gravitational attraction is so powerful that it swallows up everything near it. Even light cannot escape from it, which is why it is 'black'.

Just amazing!

AN INCREDIBLE WEIGHT

A THIMBLEFUL OF MATERIAL FROM A NEUTRON STAR WEIGHS MORE THAN ALL THE PEOPLE ON EARTH PUT TOGETHER. A NEUTRON STAR IS THE COMPACTED CORE OF A GIANT STAR THAT HAS EXPLODED, AND MAY MEASURE ONLY A FEW KILOMETRES ACROSS.



Paul Raymond

MESSAGES

FROM

THE SKY

SATELLITE TV

WORLD-WIDE COVERAGE

INTERNATIONAL DATA

TELEPHONE SOMEONE ON THE other side of the world and you will often notice little delays – less than a second long – in the conversation. It's not surprising. Whatever you say is being sent far out into space, bouncing off a communications satellite before returning to Earth to reach its destination.

Many such satellites now orbit the Earth, relaying countless TV signals, telephone calls and streams of computer data from one part of the globe to another.

Satellites also play a major role in navigation. Gone are the days when the stars and a compass were all you needed to cross the ocean. The increase in air traffic over the last few years means that it is absolutely vital to know the whereabouts of any aeroplane at any time. Today, satellite systems are in use that are

so accurate they allow the user to fix any point on or near Earth to an accuracy of ten metres.

Geostationary orbit

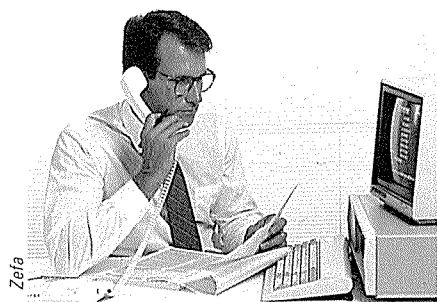
Most communications satellites have to remain in an exact spot over the Earth's surface so that receivers and transmitters on the ground can remain permanently pointed at them. They can only do this by moving in an orbit above the equator, which is 35,800 km high – about one-tenth of the distance to the Moon. This is called a 'geostationary' orbit, and once a satellite is in it, it takes exactly the same time to complete one orbit as the Earth does to spin once around on its axis (23 hours 56 minutes). This means that it seems to hang forever above the same point on the surface.

There are three main parts to a satellite communications system:

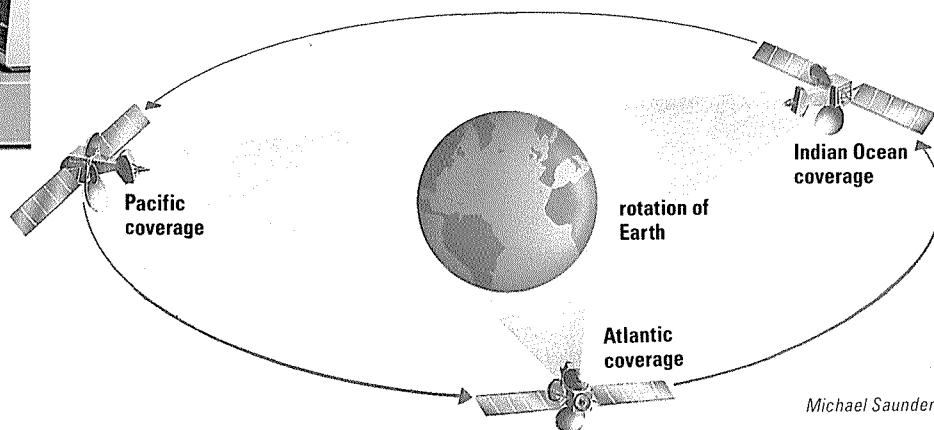
the transmitter, the receiver and the satellite itself. Information is beamed up to the satellite by large dish-shaped transmitting aerials known as ground stations. The message travels into space in the form of microwaves – short radio waves that can pass unhindered through the atmosphere.

With a small dish antenna of its own, the satellite gathers up the incoming signals. Then, almost instantly, it boosts the signals and transmits them back to a different part of the Earth. By the time the satellite transmission has arrived back at the ground it is no longer in

A reconnaissance plane pilot can keep in touch with home base via satellite and receive instructions or navigational assistance throughout his flight.



Three satellites working together in geosynchronous orbit can provide world-wide coverage, thus allowing business data to be circulated, television programmes to be transmitted and telephone link-ups (above) to be available on a global basis.



Michael Saunders



THE MOLNIYA CRAFT

When geostationary, a spacecraft can transmit to as much as 40 per cent of the globe, but it cannot reach high altitudes. This makes things difficult for northerly countries such as Russia. To solve the problem, the Soviets launched their Molniya series of communications satellites into enormously stretched out paths over the Earth's northern hemisphere. At its furthest point from Earth, a Molniya craft is 40,000 km away, and travelling slowly so that it remains visible from Russia for several hours at a time. A ground station can track the satellite and transmit or receive signals over this period.

Topham Picture Library

a narrow beam. Instead, it has fanned out over a wide area called the satellite's 'footprint'. Any suitable receiver within this footprint can then pick up the satellite's signal.

The receiving aerial also has to be dish-shaped to increase the strength of the weak signals coming from space. The microwaves coming down from the satellite strike the inside of the dish and are reflected inwards so that they all meet at the focus point, just above the centre of the dish.

Until a few years ago, the receiving dish needed to be huge. But because satellites can now amplify signals so much, modern receiving dishes are small enough to fix to the side of a house. These umbrella-sized aerials are now a familiar

sight, receiving dozens of TV channels from satellites such as Astra. Increasingly, though, cables are being used to bring the satellite signals from a central receiving dish to many houses in an area.

How it works

Seen from any point on the Earth today there are always several communications satellites above the horizon. Each satellite beams down many different signals at different frequencies. If you want to pick up a certain TV broadcast, your receiving aerial has to be pointed precisely at the right satellite, and be tuned into the correct frequency. The aerial then converts the incoming microwaves to electrical signals that are, in turn, fed to an ordinary TV set via a special converter.

Just amazing!

SHUTTLING TRASH

TWO THOUSAND LARGE PIECES OF SPACE JUNK AND COUNTLESS OTHER SMALLER PIECES ARE ORBITING EARTH. THERE ARE PLANS TO LAUNCH THE SHUTTLE AS THE FIRST GARBAGE TRUCK IN SPACE.

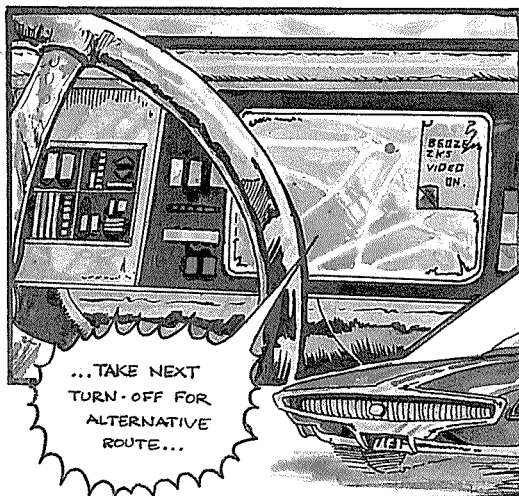


Paul Raymond

INTO THE FUTURE



▲ Cars will soon have on-board computers, fitted as standard, which will be able to pick up signals from navigation satellites orbiting the Earth.



▲ The computer will have a complete map stored in its memory, and will be able to calculate the car's position, and the distance from its destination.

IN-CAR NAVIGATION

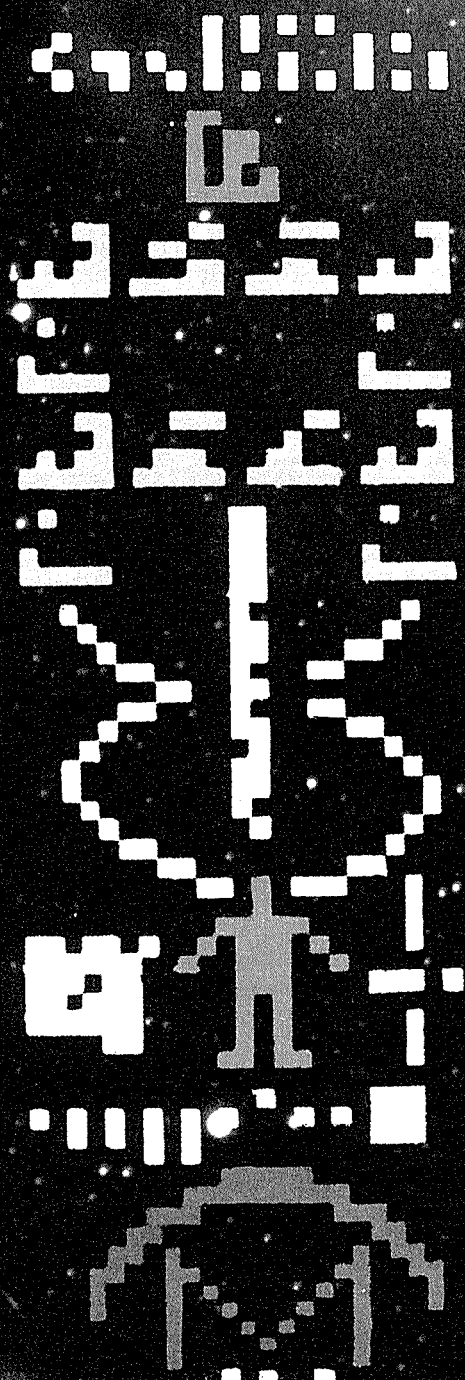


▲ A synthesized voice will then give the driver precise directions for the quickest route to follow, even taking into account how to avoid traffic jams.

Alan Burrows

- Q COMMUNICATING IN SPACE
- Q EAVESDROPPING ON STARS
- Q BEAMING MESSAGES

IN SEARCH OF ET



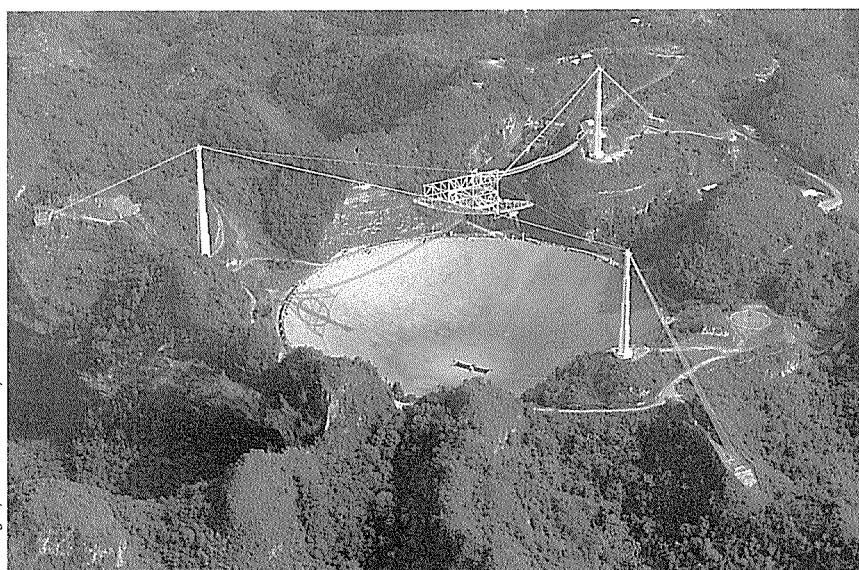
DR TOM McDONOUGH, AN astrophysicist at the California Institute of Technology, is waiting patiently for a long-distance call. If it comes, it will have taken years to arrive and will have crossed trillions of kilometres of empty space. It will be the most stupendous event in human history – a message from an alien race among the stars.

At present, several experiments are going on around the world to try to communicate with extraterrestrials using radio signals. Some, like Dr McDonough's, are attempts to eavesdrop on the stars for alien messages that may be coming from planets orbiting them. Others involve beaming out signals from Earth to let anyone who may be listening know that we are here.

How many intelligent races are there 'out there' that we might be

A coded pictogram, containing information about life on Earth, was transmitted by the Arecibo radio telescope in 1974. The pictogram was formed by some 1,679 pulses arranged into a grid 23 characters wide by 73 characters deep.





The radio telescope at Arecibo in Puerto Rico is built into a natural bowl-shaped valley and has a 300-metre diameter. It is powerful enough to communicate with another radio telescope on a planet anywhere in our Galaxy.



The Nazca drawings – giant figures scratched out on the desert at Nazca in Peru – are one of the great mysteries of the world. They show various animals, and may have been meant as a sign to the gods of the ancient Peruvians – an early form of attempted interstellar communication, perhaps. Photographs of unidentified flying objects, such as this one (inset), supposedly seen hovering over a football stadium in Colombia in 1979, are easily dismissed as hoaxes.

able to contact? The simple answer is, no one can be certain. Until scientists find just one example of life beyond the Earth, we cannot be sure that there are any extraterrestrial beings.

One of the first people to mount a search for alien radio messages was the American astronomer, Frank Drake, in 1959. He wrote down a formula for calculating the number of technological civilizations in the galaxy. This took account of factors like the fraction of stars with planets, the fraction of suitable planets per planetary system, and the fraction of planets where life arises. However, the formula gives answers that are only as good as the estimates put in by individual scientists.



Alien broadcasts

Unfortunately, listening for extraterrestrial messages is not as simple as tuning into an ordinary radio station. Not only are there billions of stars to choose from, but there are also billions of different radio fre-

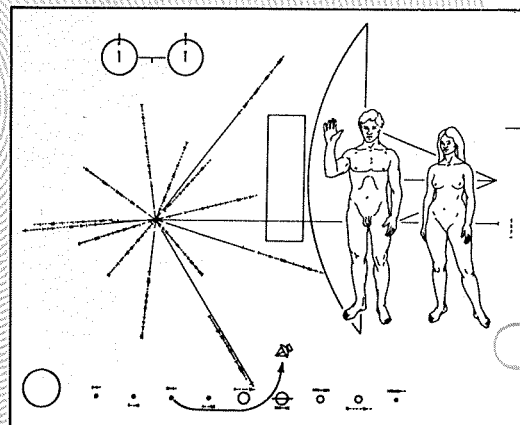
quencies at which an alien race might choose to broadcast.

Today, major advances in electronics have greatly speeded up the quest for E.T. Instruments like the giant radio dish at Arecibo, in Puerto Rico, have been linked to a special new device known as a multichannel spectrum analyzer. While the Arecibo dish is pointed at any given star in its search for alien messages, it tunes in to 27,000 different frequency bands. The analyzer linked to it then breaks each band into 74,000 channels and, using a computer, decides if each of these is broadcasting static, natural signals, or artificial signals. It also has to work out whether artificial signals come from some nearby man-made source, or from deep space.

The prospect for success is improving all the time as new, faster analysis equipment is developed. According to Dr McDonough, 'there is an excellent chance that by the year 2000 we will find the first indisputable proof of another civilization in space'.

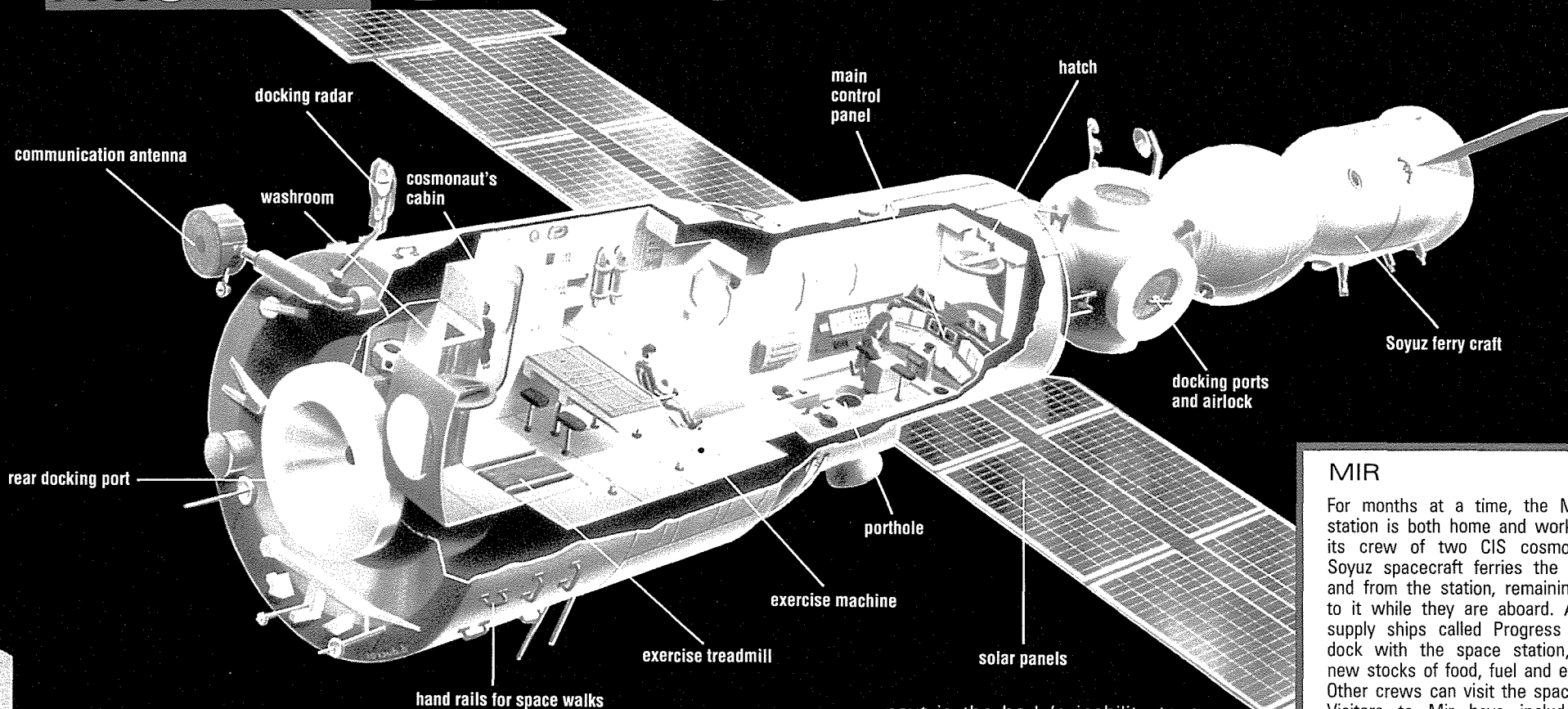
INTO THE UNKNOWN

Engraved plaques were carried by the *Pioneer 10* and *11* space probes to Jupiter, both containing messages devised by the well-known astronomer, Carl Sagan. Sagan was convinced that the information, written in scientific language, would easily be interpreted by any civilization clever enough to intercept one of the probes. He also believed that the most difficult part of the message for an alien to understand would be the male and female figures. But he thought that their oddity would suggest they were biological and not technological.



A HOME IN SPACE?

- ARTIFICIAL GRAVITY
- FARMING IN SPACE
- RADIATION SHIELDING



MIR

For months at a time, the Mir space station is both home and workplace for its crew of two CIS cosmonauts. A Soyuz spacecraft ferries the crews to and from the station, remaining docked to it while they are aboard. Automatic supply ships called Progress can also dock with the space station, bringing new stocks of food, fuel and equipment. Other crews can visit the space station. Visitors to Mir have included Helen Sharmon, the first Briton in space, who spent a week aboard in May, 1991. Additional sections docked to Mir provide more working space in which to carry out experiments in the weightless conditions of orbit. The two cosmonauts can leave the space station through a hatch to carry out repairs to the station and its wing-like solar panels that generate electricity. Experience aboard Mir has shown that humans can live in space for long periods without harm.

SPACE EXPLORATION IS hugely expensive — it cost \$25 billion to put the first man on the Moon. But now that a great deal of expertise has been gained in space technology, the space agencies are earning money by providing services to military, scientific and industrial organizations.

Placing communications satellites in orbit is frequently demanded

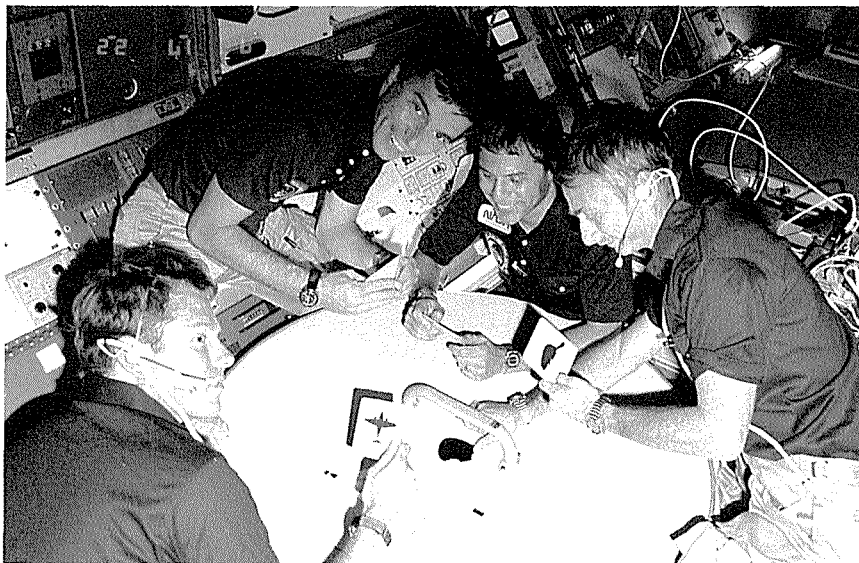
as a service by scientific establishments which pay for various experiments to be carried out in space. Industry provides the money to set up factories in space for special manufacturing processes designed to take advantage of the lack of gravity. Eventually, this will lead to the establishment of huge, permanently staffed space stations.

Away from Earth's gravity, one serious disadvantage for the astro-

naut is the body's inability to produce calcium for the bones. Calcium loss can be as high as two per cent in a month. At that rate, a long space trip could permanently cripple a space traveller. For those carrying out a tour of duty at a space station, long periods of zero gravity would be intolerable. Therefore space stations will mimic Earth's gravity.

To do this, they will rotate, producing centrifugal force at the outside edge. A practical design for such a rotating model is a circular





continuous cylinder, like a thin doughnut.

A large, rotating, circular space station will provide an Earth-like environment, which could be enhanced with plants and trees, and even water lakes.

Practical problems

On spaceships and small space stations, where it is not practicable to counteract the effects of zero gravity, simple functions such as eating and going to the lavatory create major problems. Unless care is taken when eating and drinking, lumps of food and globules of liquid will sail uncontrollably around the cramped living space. Early space food included meals in squeeze-bags, which delivered nutritious sludges directly into the mouth via a tube. But these meals proved unpopular, so astronauts now have food that resembles what they would eat back on Earth.

In zero gravity conditions, special devices are necessary to collect the astronauts' solid and liquid wastes.

Space commodes are fitted with lap straps, as well as hand and foot holds, to keep the astronaut clamped securely to the close-fitting seat. Air jets and air suction move solid wastes down into the chamber, where they are fragmented by a rotating metal blade. After being dried, the wastes are stored for later analysis.

Urinating is achieved either via personal 'relief tubes', with different fittings for men and women, or through a unisex fitted cup. Urine is vented out into space, where it flash freezes instantly into ice crystals. Sometimes the vented urine builds up into bulky icicles, which have to be removed from the outlet port by means of an external robot arm.

On both large stations and small spacecraft, water will need to be

Space laboratory work means spending many hours carrying out routine checks. Leisure pursuits are important to combat boredom.

constantly recycled, for drinking and for reconstituting dehydrated foods. Filtration plants will recycle water, urea and carbon dioxide from the space-travellers' body wastes to produce purified water and oxygen.

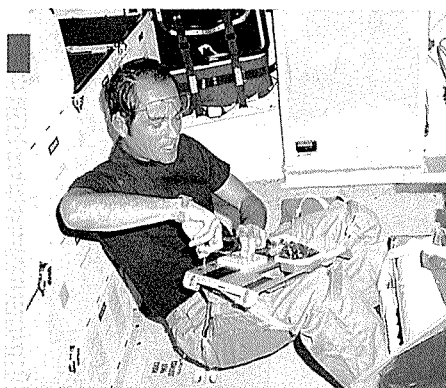
Water would also be produced as a byproduct of the fuel cells, which would create electricity by combining hydrogen and oxygen.

Food production

For long, unserviced flights, food will have to be synthesized in small micro-biological units. On a large space station, with artificial gravity and climates, food could be produced by growing plants. It would be more economic to grow the plants in solutions of nutrient, rather than in soil. Animals would be relatively uneconomic to produce for food, although some could be reared to add variety to meals. Home-grown items would be good for morale, but would be an expensive luxury.

Safety in space

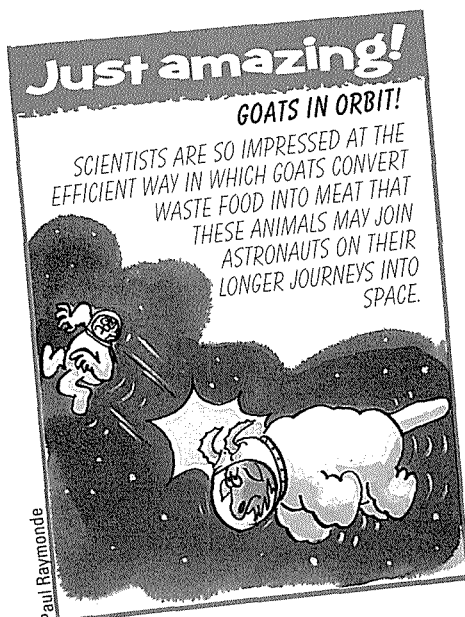
Radiation is always a hazard in space, particularly at the time of major solar flares. These release high-energy protons capable of piercing simple shield systems. During non-flare periods the annual radiation dosage in space would be about 20 times higher than the US standard for maximum allowable background radiation on Earth.



SPACE FOOD



A typical daily meal on board an American spacecraft could include smoked turkey, mixed vegetables, cream of tomato soup, and strawberries. Peanuts and dried fruit can be eaten as snacks. Freeze-dried dehydrated foods can be reconstituted by squirting them with cold water from a gun connected to the food pack. A hot-water gun is available for making tea, coffee and cocoa. Drinks are sucked through a tube or squeezed into the mouth from a flexible plastic container.



SATELLITE KILLERS

- INTERCEPTORS
- SPACE MINES
- HIGH-ENERGY LASER

MILITARY SATELLITES ARE the long-range eyes and ears of the armed forces of several nations. If war breaks out, both sides will aim to destroy the other's military spy satellites with ASAT (anti-satellite) weapons.

Over three-quarters of all satellites launched are intended for purely military purposes. They relay military radio messages, eavesdrop on radio and radar signals, and take detailed photographs of troop and ship movements, airfields and missile bases. They can also detect and track enemy missiles, and they help ships and aircraft to navigate, and missiles to find their targets accurately.

Russia's main ASAT system is based on killer satellites, while the USA has concentrated on ASAT missiles. In the future, both countries will probably add laser and particle beam weapons to their ASAT arsenals.

● Killer satellites

The Russian killer satellite system uses a version of the SS-N-9 missile to put an interceptor into orbit that can attack targets in orbits of up to 5,000 km above the ground.

The interceptor is put into a lower orbit than the enemy satellite, to allow it to catch up with its target. Once correctly positioned, it fires its engines to boost it into the target's orbit and then homes in on it, guided by radar or infra-red sensors. As soon as it is close enough, its high-explosive warhead detonates and destroys the target with a hail of shrapnel.

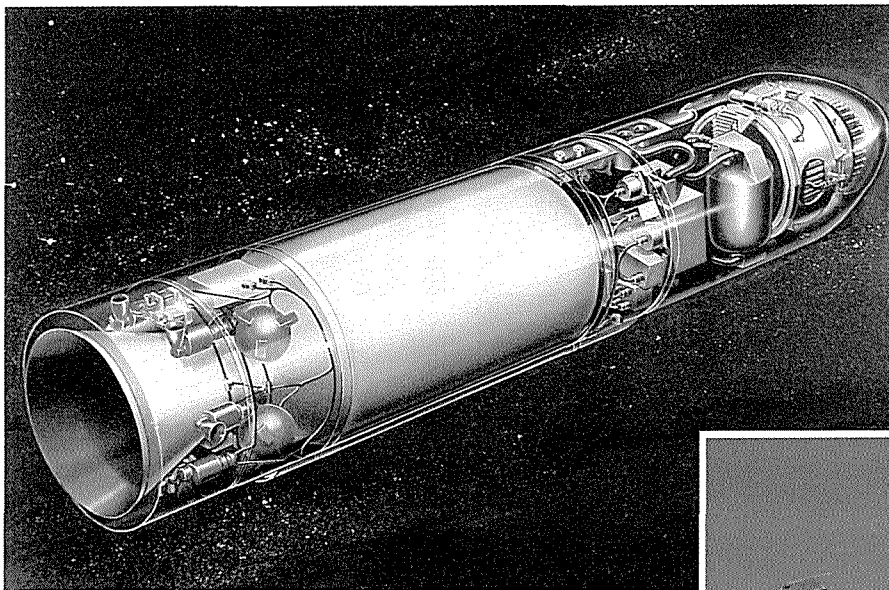
● ASAT missiles

An alternative to using a killer satellite is to knock out enemy satellites with missiles launched either from the ground or from aircraft. Russia may have a ground-launched ASAT missile, developed from its ABM-1

A US ground-launched missile heads for the skies. These are capable of destroying satellites circulating in low orbits.

Hertz/Liaison/Frank Spooner Pictures





US Department of Defense/USAF

based. To prevent the beam from being spread and weakened by the protons colliding with air molecules in the atmosphere, it could be fired down the middle of a laser beam. The laser would ionize the air molecules, creating a 'tunnel' for the proton beam to pass through, uninterrupted towards its target.

The upper stage of the US Air Force's ASAT missile. The two-stage missile burns out, leaving the miniature homing vehicle (in front) to lock on to its target, which it destroys.

Galosh anti-missile missile, that is capable of destroying satellites in low orbits. The Americans have developed an air-launched missile.

The American ASAT missile, launched from a modified McDonnell Douglas F-15 fighter, is a two-stage, 5.4 metre-long missile carrying a device called a miniature homing vehicle (MHV).

To launch the missile, the F-15 accelerates in level flight and then climbs steeply, releasing the missile as it zooms upwards. After the first stage of the missile has burnt out and separated, the MHV continues upwards powered by the second stage and its infra-red sensors search for, and lock on to, the target satellite.

In the final phase of the attack, the MHV separates from the second stage and hurtles towards its target, steered by 56 tiny single-shot rockets. The MHV is only 33 cm long and 30.5 cm in diameter, and it carries no explosive warhead

The F-15 with an anti-satellite missile loaded can fly almost anywhere to intercept. The missile can be launched during a steep subsonic climb.

US Department of Defense/USAF



— it simply rams the target to destroy it. But at a collision speed of around 13 km per second, the impact is reckoned to be the same as a direct hit by a 155 mm artillery shell.

Beam weapons

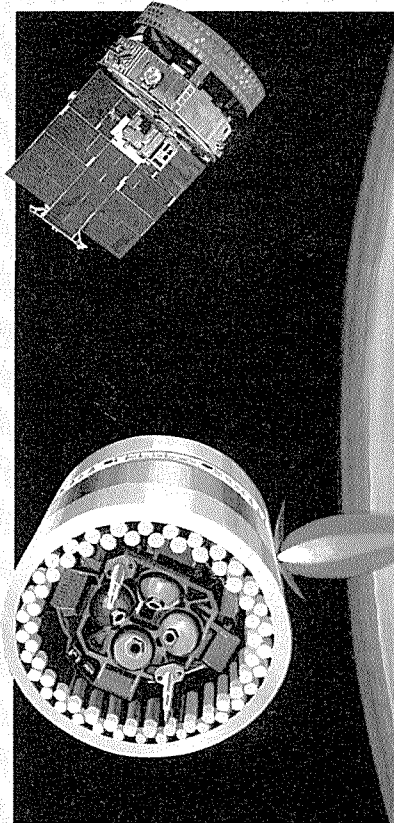
Much of the anti-missile technology being developed by the Americans for their Strategic Defence Initiative ('Star Wars') project, and by Russia for its own version of it, could be used against satellites.

High-energy lasers, ground-based or carried on aircraft or satellites, could blind a satellite's sensors, make it overheat and stop working or even physically destroy it. Photographic surveillance and weather satellites are especially vulnerable to laser attack, because they travel in low orbits and their downward-looking optical and infra-red cameras are easily blinded by lasers.

Future satellites of this type will be able to defend their cameras against laser attack. Radar sensors on the satellite will detect the tracking radar used to guide the laser, and activate systems that shield the cameras or tilt the satellite away from the direction of the laser beam.

Particle beam weapons would use a beam of sub-atomic particles — protons — to destroy a satellite's electronic circuits. Because of the enormous amounts of energy needed to produce these proton beams (the Russian system is powered by small nuclear explosions), particle beam weapons would probably have to be ground-

ADVANCE WARFARE



US Department of Defense/USAF

Instead of killer satellites being sent up in the early stages of a war, they could be launched days, weeks or even years in advance and left in orbit close to their intended targets. These 'space mines' could then be commanded to destroy the enemy's satellites as soon as the first shots were fired.

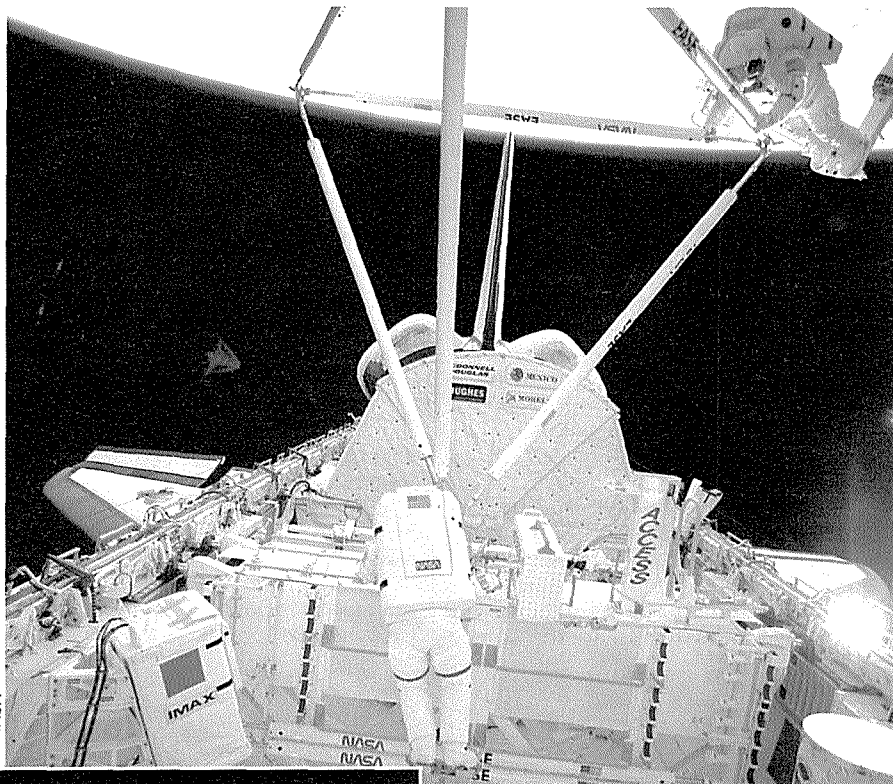


ASTROSTRUCTURES

- SPACE STATIONS
- WELDING IN SPACE
- MINING THE MOON

HUMAN BEINGS HAVE BEEN living and working in space for more than 30 years, but little construction work has been done there. However, in the mid-1990s, the building of the international Freedom space station will begin. Novel building designs and assembly methods have been developed for the hostile environment of space.

The largest orbiting space vehicle so far, Skylab, was launched in 1973 as a single unit. It consisted of the third stage of a giant Saturn V rocket, of the type that launched the Apollo Moon missions. What would have been the rocket's hydrogen fuel tank had been converted to living quarters, while the original oxygen tank below the crew



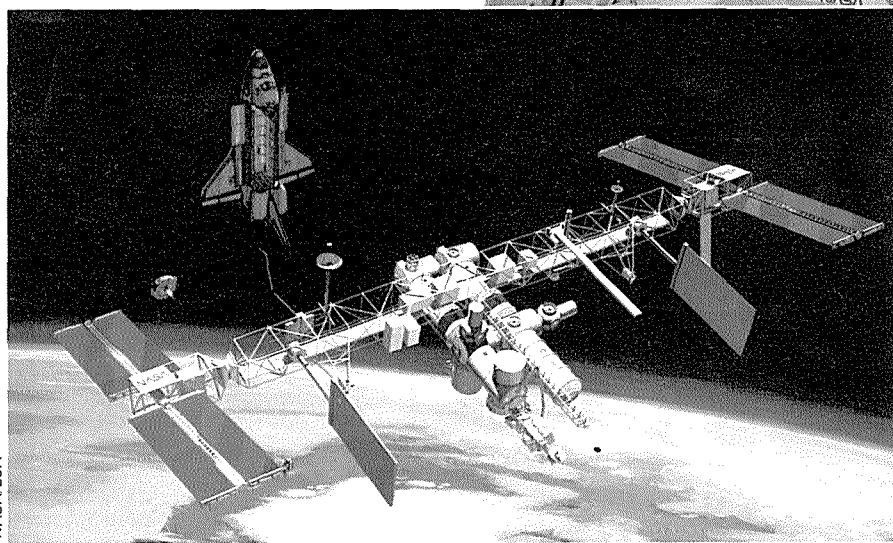
Space Shuttle astronauts in Earth orbit try out structure assembly techniques in weightless conditions.

The Freedom space station, an international project planned within the next decade, will have laboratory modules for studying materials, and plant and animal life under low-gravity conditions.

in October 1969. Now NASA has designed an automatic beam builder that would use welding to construct trelliswork beams. Ribbons of a graphite/epoxy resin compound coated with aluminium would be unwound from spools. Cross-pieces would be automatically cut and welded onto these. When a sufficiently long beam had been constructed in this way it would be cut off, and astronauts would attach it to the space station structure.

Materials such as the graphite/epoxy combination are used in space because they do not deform greatly under extreme variations in temperature, which occur on the sunlit and shadowed side of space stations and satellites.

Assembling structures in space



quarters was used to store waste.

Assembling structures in orbit has great advantages over launching them ready-made from the Earth, as Skylab was. Because objects in orbit are weightless, they can be made very much larger than anything that could be carried up on a rocket. Also, they can be much more flimsy than a similar building on the ground.

The space station will be far larger than Skylab. It will be assembled from parts, or 'modules'. These

will not be converted rocket parts but specially built units, each carried into orbit in the cargo bay of a space shuttle. A long robot arm will haul each module out of the shuttle and 'clip' it on to the space station assembly by means of snap-on connectors.

Robot welders

Welding may be used in building the space station. The first experiments in space welding were made by the Soviet cosmonaut, Valery Kubasov,

NASA/ESA



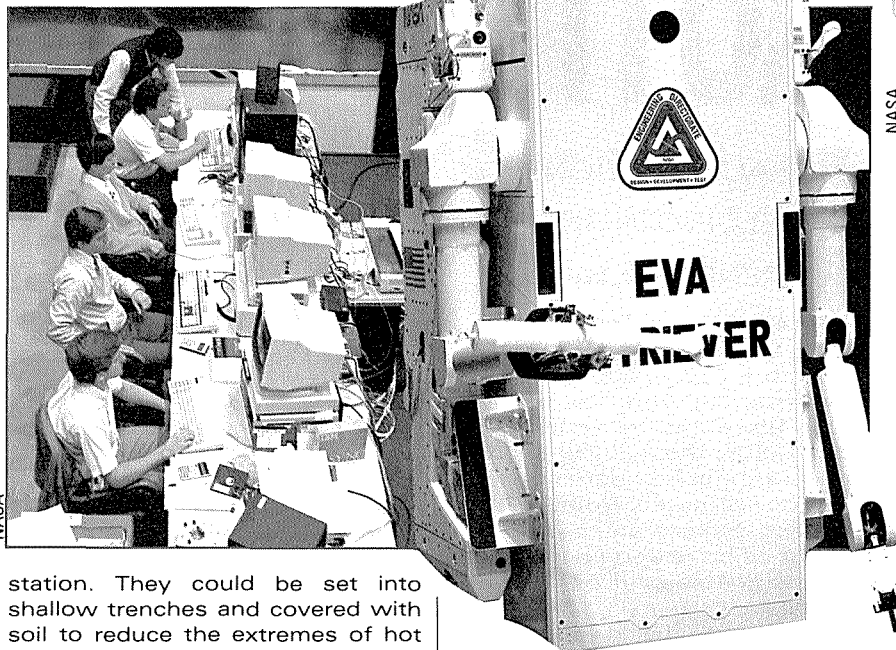
may be done with the aid of robot arms like the 50 metre arm now used on the shuttle. The 'end effector' (hand) on the arm will be controlled by an astronaut on-board the spacecraft.

Space mechanics

For other jobs it will be necessary for an astronaut to get as close as possible, so an EVA retriever ('extra-vehicular activity') will be used. The astronaut may ride on a 'manned remote work station', mounted on the end of the shuttle's robot arm. The worker might wear a spacesuit and be attached to the station by foot restraints, or he or she could be in shirt sleeves inside a pressurized 'hut'.

For yet other jobs the workers could be free-flying, by means of jetpacks worn on the back, or in pressurized work-stations that would be 'mini-spaceships'. However, robots may play a part in this area too. Already NASA is planning a free-flying robot worker called the EVA Retriever.

Space mission scientists test the human-sized robot called EVA Retriever. It will retrieve tools and other items accidentally allowed to drift away while working in space.



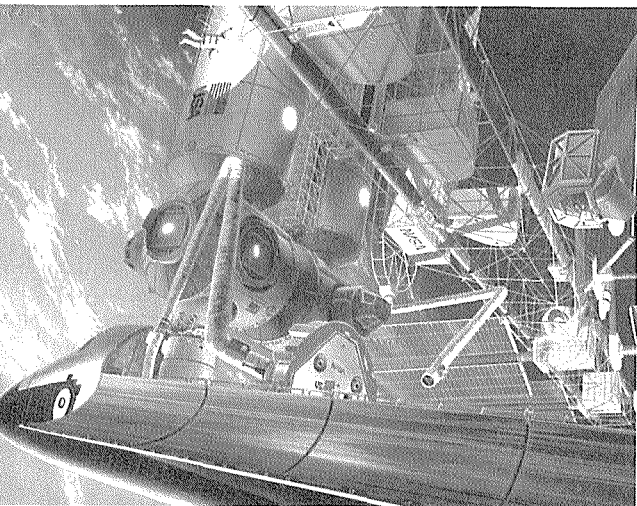
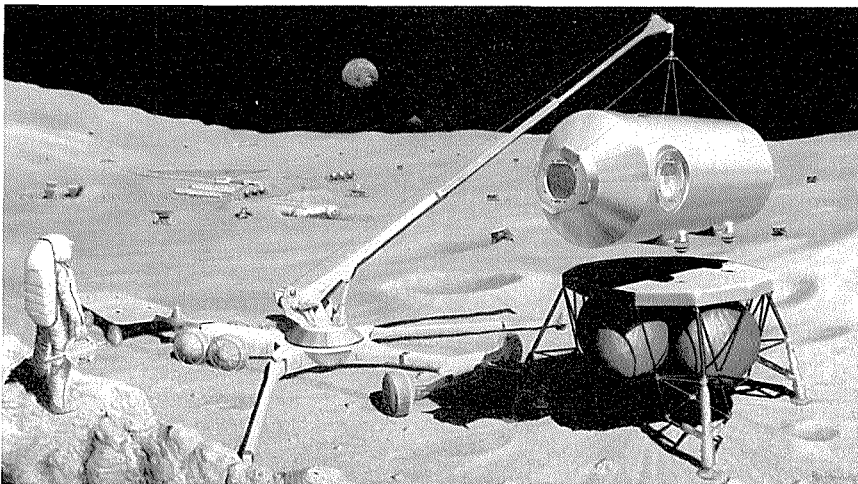
station. They could be set into shallow trenches and covered with soil to reduce the extremes of hot and cold and the threat of cosmic rays.

However, it would be much cheaper to make building materials on the Moon from lunar rock.

Already 40 grams of the precious rock brought back by the Apollo missions have been used to make tiny quantities of concrete. The experiments seem to have been successful.

There are plans to extract useful materials from the Moon rocks. Oxygen, for example, could be used to make rocket propellants and to supply air to the Moonbase.

A manned Mars colony may be started in the 21st century. It would be cheaper to transport materials from the Moon than from the Earth. But first the techniques of lunar mining and manufacturing must be mastered.



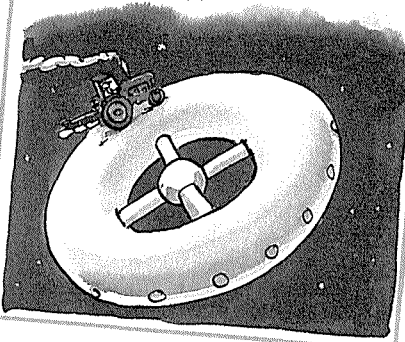
To start building on the Moon, modules delivered by lunar landers will be unloaded by crane and hauled to the site.

Docking a space shuttle and unloading equipment from its cargo bay will become a routine operation when space stations like this have been constructed in Earth orbit.

Just amazing!

ARTIFICIAL WORLDS

FUTURE SPACE COLONIES WILL BE SELF-SUPPORTING COMMUNITIES LIVING IN HUGE ROTATING RINGS, SPHERES OR CYLINDERS WITH THEIR OWN INDUSTRIES AND AGRICULTURE.



Paul Raymonde

DEEP IN SPACE, A GIANT telescope locks on a distant star. The signals analysed back on Earth indicate planets are orbiting. Where there are planets, there could be life.

This is just one of the discoveries that could be made by a new generation of Space telescopes about to be put into orbit round our planet. The Hubble Space Telescope, launched in 1990 via the Space Shuttle, heralded a new age of knowledge of the Universe, despite some early technical troubles.

Putting a large telescope into orbit is very expensive – so why not use the big telescopes on Earth to tell us about distant objects in the sky? The simple answer is that the atmosphere filters out a great deal of light. It is constantly moving, making images in telescopes wobbly and lose definition.

Ground telescopes

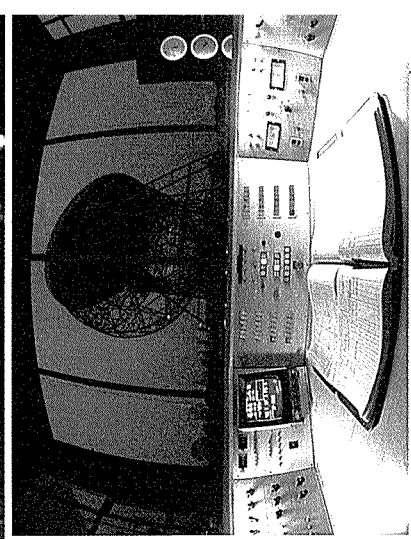
Since people first looked through simple refracting telescopes hundreds of years ago, the race has been on to build bigger and better telescopes. Lately, all the really big 'scopes have been reflecting telescopes.

These are usually sited a long way from the bright lights of cities, and high up on a mountain where the air is thinner and calmer. Very few giant observatory telescopes can be looked through directly. Most are designed to produce images that are recorded photographically or electronically. Many use image intensifiers to amplify light far fainter than the eye can detect.

A computer-enhanced photograph of spiral galaxy M51, only 2.4 million light years from our own Milky Way

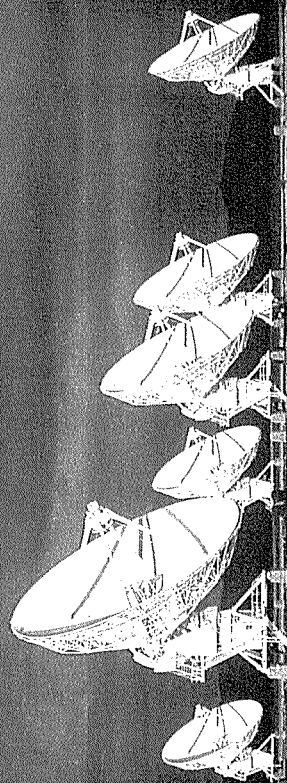
Dr Jean Loree SPL

THE LIGHT WINDOW SPACE TELESCOPES VERY LARGE ARRAYS



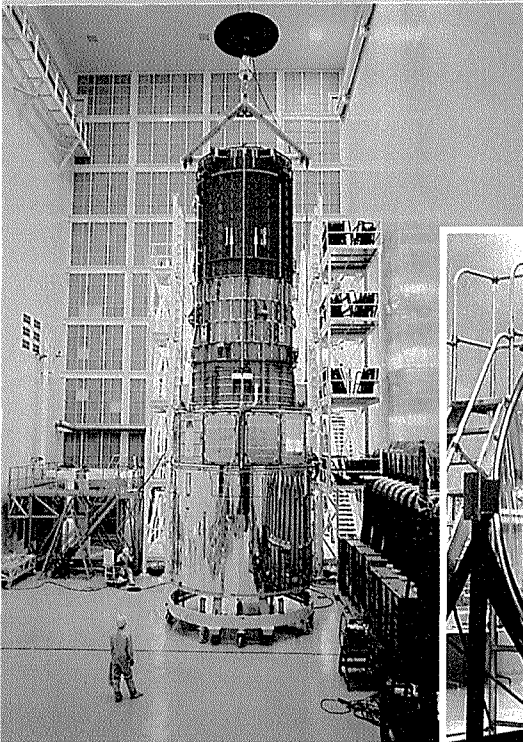
David Parker/SPL

Arrays of radio telescopes may be connected to others miles away to create VLAs (very large arrays). The world's first giant radio 'scope' is visible through the window of the control room at Jodrell Bank, England (inset right).

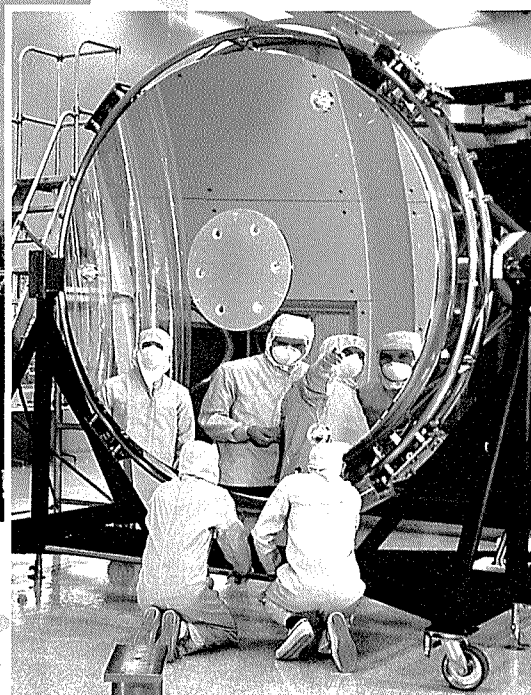


Tony Stone Photo Library, London





The Hubble Space Telescope, ready for lift off. It should see seven times further into space than astronauts have ever seen.



The mirror from the Hubble 'scope has a special reflective surface. Technicians must wear masks and gowns to ensure absolute cleanliness – any speck of dust may mar the surface.

The telescope with the single biggest mirror is at the Mount Pstukhov Crimean Observatory in the USSR. Its mirror is 6 metres across, compared to the 5.1 metre mirror of the telescope at Mount Palomar in the USA. However, the Palomar mirror is a bit better because the Crimean mirror is so big it actually distorts under its own weight.

Several new ground-based telescopes are planned, using new

glass-moulding technology. One of these, at Mount Graham in Arizona, will have two giant mirrors – each 8 metres across giving the light gathering power of a mirror 11.3 metres across.

Some telescopes work in the infra-red section of the spectrum and need an array of special detectors. A new detector is being installed at the Mount Lemmon 1.5 metre reflecting telescope. It has 16,384

Telescopes in space can pick up radiation in the X-ray, ultraviolet, infra-red and long wave radio wavelengths that cannot be detected on Earth. X-ray telescopes, such as those in the MIR and Ginga satellites, detect X-rays that are generated by gas falling into super-dense neutron stars. Other radiation, especially those at very short wavelengths, are produced in quasars and in the heart of galaxies where black holes with the mass of 1,000 million stars are actively sucking in material.

Collecting radiation

Orbiting telescopes that detect ultraviolet in orbit produce false colour images of very hot stars – these generate a great deal of ultraviolet radiation. They have a mirror covered with a reflective coating that focuses light. The image is detected by an array of cells sensitive to ultraviolet radiation.

The ultraviolet region of the electromagnetic spectrum (91–320 nanometres or $91-320 \times 10^{-9}$ metres) is particularly interesting to astronomers. Radiation at these wavelengths can give information about cold dust clouds as well as exotic objects such as quasars – the brilliant centres of young galaxies far off in the universe. The hot stars are much brighter at ultraviolet wavelengths. A star with a surface temperature of $40,000^{\circ}\text{C}$ is approximately one hundred times brighter in ultraviolet than in visible light. (Our Sun has a surface temperature of only about $6,000^{\circ}\text{C}$.)

Radio telescopes on the ground take advantage of the fact that the

The River Nile in flood, seen from Space. Orbiting telescopes can also be used to examine the Earth – to predict weather and natural disasters and to reveal resources.

A digitized, colour-coded image of an exploding star, or supernova, from the International Ultraviolet Explorer satellite.

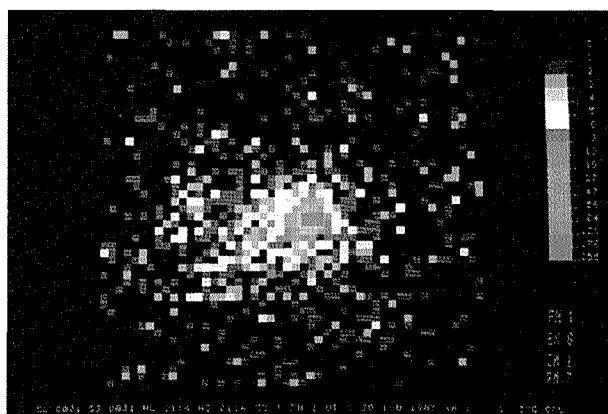
photodiodes, in an array 128 by 128, made from a compound of cadmium, mercury and tellurium. This allows astronomers to take pictures of the infra-red emissions from whole galaxies.

Orbiting telescopes

But there are limits to what can be seen through the Earth's atmosphere, even when the telescope is sited near the top of a very high mountain above most of the air. This is where orbiting telescopes come in.

atmosphere is particularly 'transparent' to microwave radiation and medium wave wavelengths section. Radio 'scopes collect radiation in a dish and beam it to a detector. The signals are relayed to a computer and interpreted into images that show the shape of an object and the strength of the emissions of the radio source in the sky.

To make radio astronomy telescopes as powerful as possible, telescopes far apart are linked up to form what are known as Very Large Array (VLA) telescopes.



Gamma/Frank Spooner Pictures

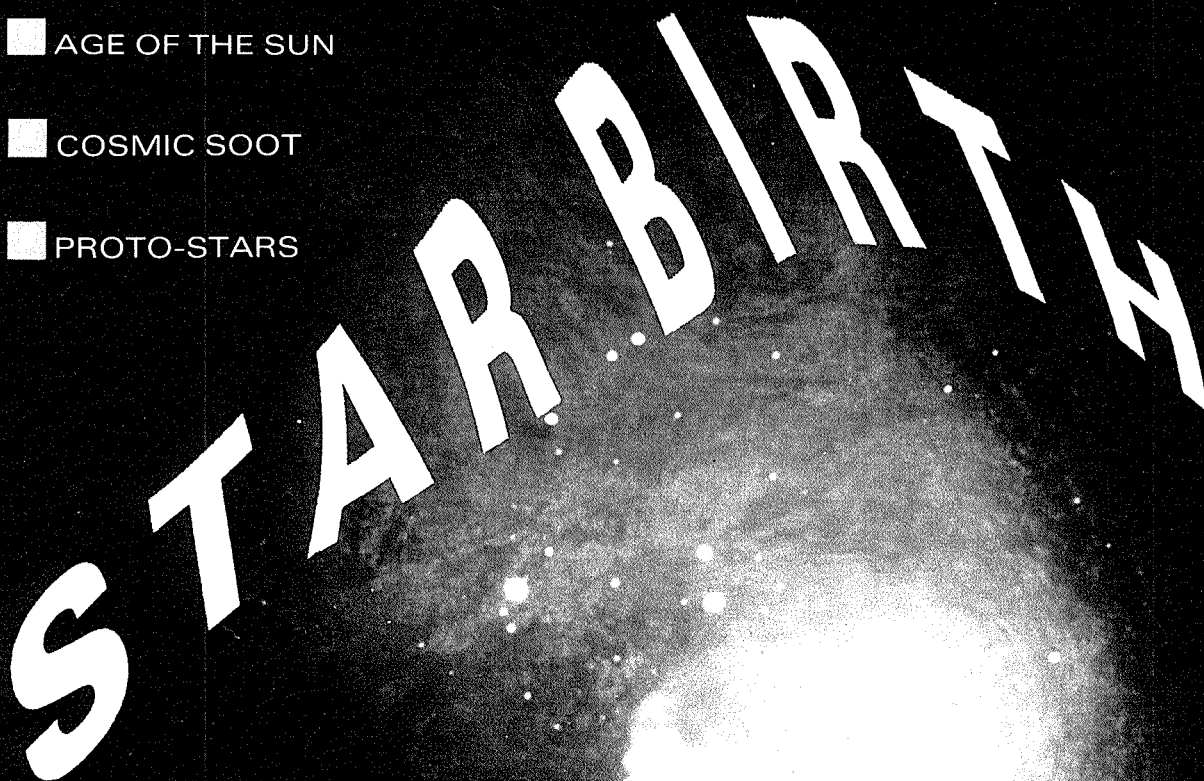
NASA

■ AGE OF THE SUN

■ COSMIC SOOT

■ PROTO-STARS

STAR BIRTH



Four new stars – known as the Trapezium Cluster – are clearly visible in the swirling gas and dust of the Orion nebula.

NASA SPL

STARS ARE BORN IN VAST clouds of dust and gas, and take many years to evolve into the brilliant objects that illuminate our night skies

Stars are immense balls of hydrogen and helium, which shine by the same nuclear reactions that power hydrogen bombs. The Sun around which the Earth and other planets revolve is a typical middle-aged star.

At its core hydrogen is being converted to helium at the rate of 4 million tonnes per second,

which releases vast amounts of energy. Though this sounds an enormous figure, astronomers know that there is enough of this 'nuclear fuel' to power the Sun for another five billion years.

It has been known for some time that stars are formed in nebulae – clouds of dust and gas – some of which can be seen in the night sky. To the naked eye, the Great Nebula in Orion appears as part of the mighty hunter's sword. But many nebulae are cold and dark and cannot be seen with even the most

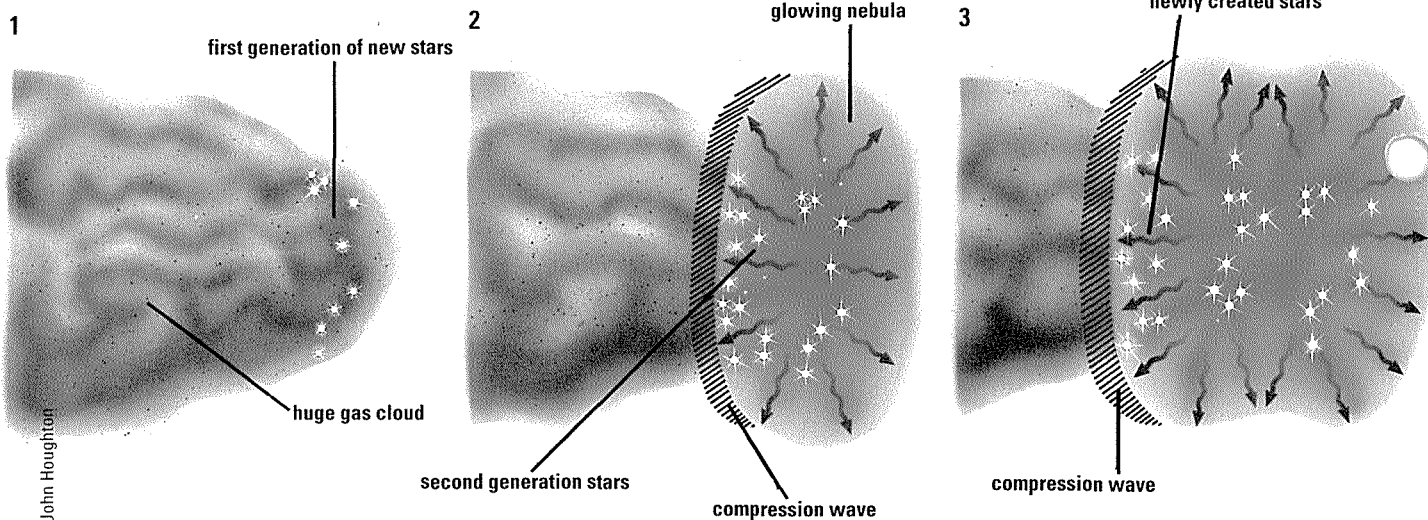
powerful optical telescopes.

In 1983 a satellite called IRAS – the Infra-red Astronomical Satellite – was launched. It revealed that many nebulae extend much further than they appear to in ordinary light, the outer regions of dust and gas glowing at the longer infra-red wavelengths.

The dust is a vital ingredient in starbirth, even though it only accounts for 0.1 per cent of the material between the stars in our Galaxy. Some of it is made of ice,



HOW STARS ARE BORN



John Houghton

One theory of star creation. A first generation of stars forms near the surface of a giant cloud of gas, 1. Their heat compresses it, 2, creating more new stars, 3.

It contains ice crystals, silicon and even organic compounds, such as formaldehyde. But most of it is carbon in the form of small dust grains — cosmic soot. Other molecules have been revealed by radio telescopes that can, literally, 'tune into' their atomic vibrations.

Stars go nuclear

The dust and gas gradually begins to come together under the influence of its own gravity, helped by other processes that compress the gas — such as collision with the expanding shells of material thrown off by dying stars. Massive stars may undergo a tremendous supernova explosion, in which most of their material is thrown off into space, adding greatly to the dust and gas already in the vicinity, and further compressing the gas. Eventually, in regions where the density of mate-

Dr Fred Espenak/SPL

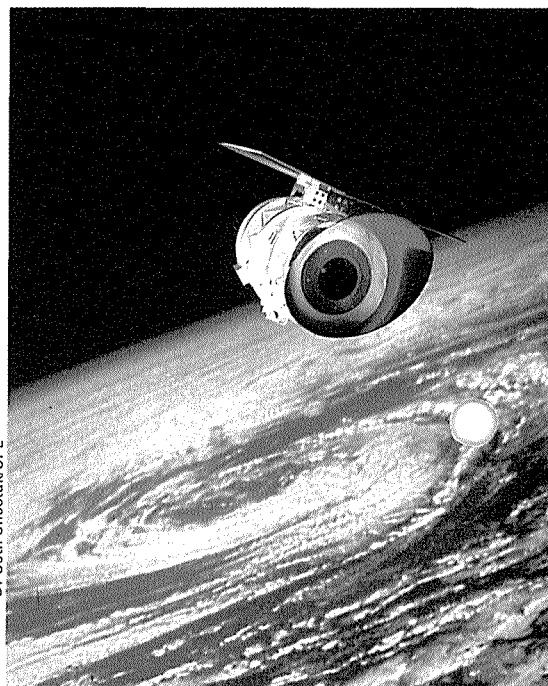


rial is sufficiently great, the dust and gas condenses into a vast swirling concentration — a proto-star.

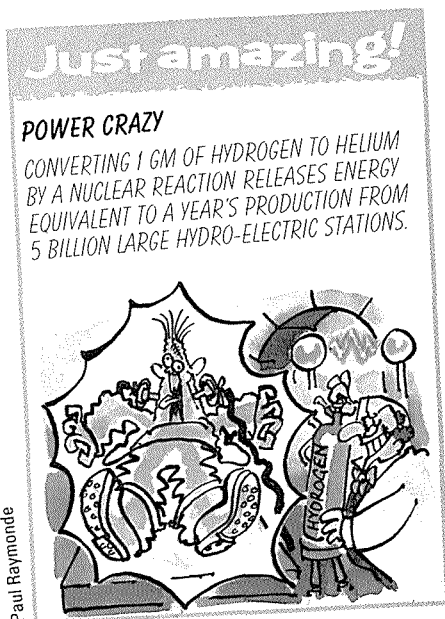
The proto-star continues to contract (shrink), and as it does so the temperature at its centre increases. The more massive the proto-star, the higher its central temperature. Some proto-stars are so small that they will never become hot enough for nuclear reactions to begin. But a proto-star of sufficient mass will, after many tens of thousands of years, 'go nuclear' (start to shine), when its central (core) temperature reaches ten million degrees Celsius. This is the moment of starbirth.

The new-born star emits large quantities of radiation, which can disrupt the formation of other stars in the vicinity. However, after its violent birth, the star settles down to a period of relative stability. Any remaining dust and gas in close proximity to the star may clump together to form planets, comets and meteoroids, such as in our own Solar System.

The infra-red astronomical satellite (IRAS) revolutionized our view of starbirth. It circles the earth 14 times a day.

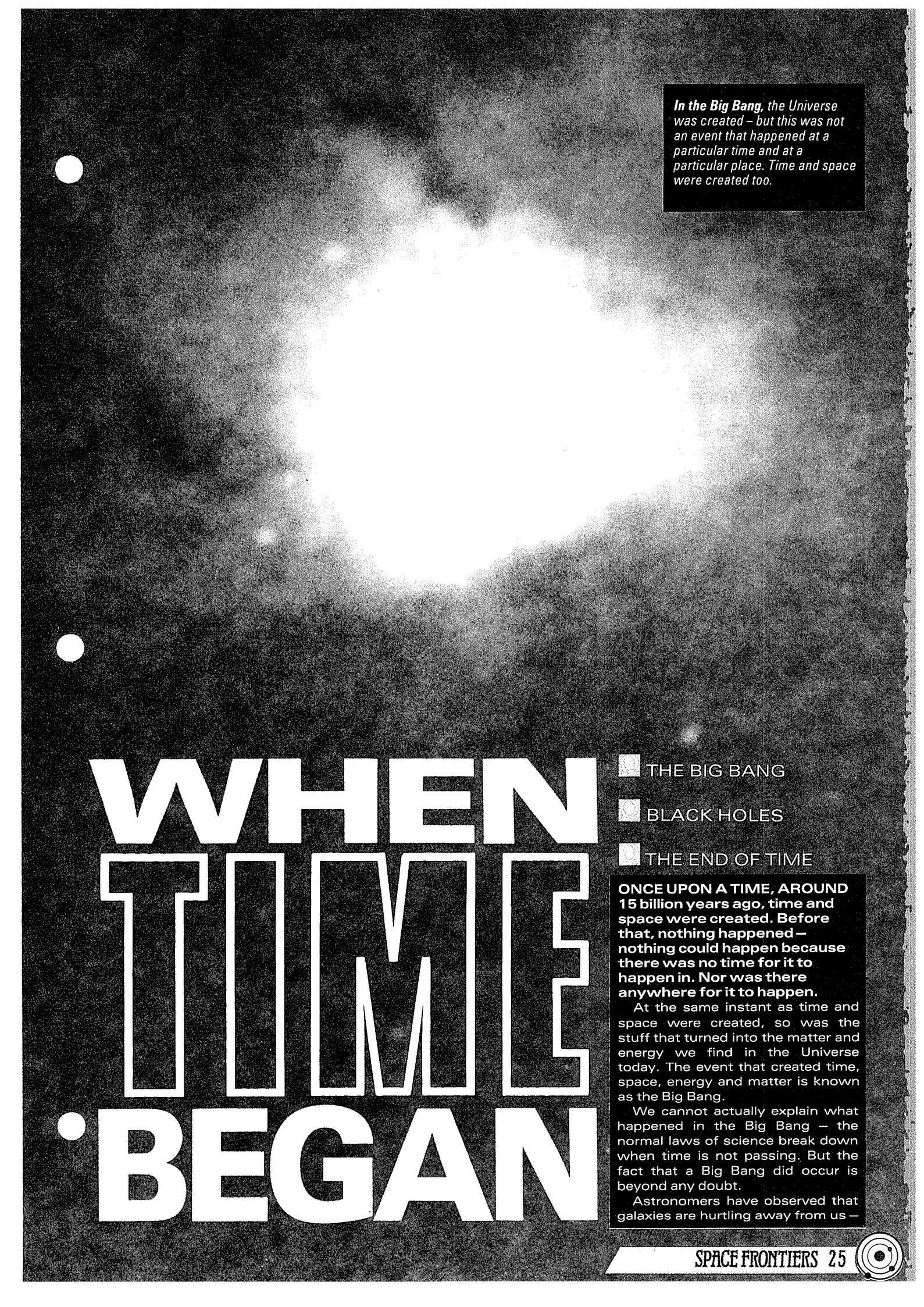


Dr Seth Shostak/SPL



Paul Raymond





In the Big Bang, the Universe was created – but this was not an event that happened at a particular time and at a particular place. Time and space were created too.

WHEN TIME BEGAN

■ THE BIG BANG

■ BLACK HOLES

■ THE END OF TIME

ONCE UPON A TIME, AROUND 15 billion years ago, time and space were created. Before that, nothing happened – nothing could happen because there was no time for it to happen in. Nor was there anywhere for it to happen.

At the same instant as time and space were created, so was the stuff that turned into the matter and energy we find in the Universe today. The event that created time, space, energy and matter is known as the Big Bang.

We cannot actually explain what happened in the Big Bang – the normal laws of science break down when time is not passing. But the fact that a Big Bang did occur is beyond any doubt.

Astronomers have observed that galaxies are hurtling away from us –





sudden inflation

big bang

particle soup

Closed Universe

universe collapses under its own gravity

big crunch

Two theories of the future. If there is enough undiscovered 'dark' matter in the universe it will collapse again under its own gravity into a big crunch. If there is not, the expansion will never slow and the universe will go on getting bigger forever.

Open Universe

first atoms

the present

matter breaks down

universe goes on expanding forever

Atom smashers like this giant synchrotron at the nuclear research centre in Geneva use very high energies to recreate the conditions that existed soon after the Big Bang. Inside, massive magnets accelerate tiny particles round a huge 'racetrack' (below), then smash them into each other.

PHOTO CERN

and from each other — at great speeds. In fact, they are not moving *through* space. It is the space between them that is expanding. Imagine the galaxies as dots on a balloon. As you blow up the balloon, the dots get farther apart.

From the fact that space is expanding, it has been deduced that everything was once together in one 'place' — the 'place' where the Big Bang occurred. However, what was once a single point is now a huge sphere all around us.

Because light takes time to reach us, looking out into space is like looking back in time. For example, the light from Barnard's Star takes nearly six years to reach Earth, so when we look at Barnard's Star we see it as it looked six years ago. It could have blown up in the meantime and we would not know yet — not till six years after the explosion. Similarly, someone living on a planet orbiting Barnard's Star would, if they could observe the Earth see what was happening six years ago.

If you look past Barnard's Star, out towards the edge of the Uni-

PHOTO CERN

Scientists look for quarks among the resulting cloud chamber tracks. These tiny particles existed after the Big Bang.

verse with a radio telescope, you can 'see' back billions of years to almost the time of Big Bang itself.

The revolutionary physicist Albert Einstein showed in his General Theory of Relativity that time slows in the presence of gravity. So back at the beginning of time, when all matter was so tightly compacted that its density — and its gravity — was huge, time must have passed much more slowly than it does now. So we can only begin to understand what happened in the Big Bang a short while after the beginning of time.

When the Universe was just 10^{-43} seconds old — that is, one ten million, trillion, trillion, trillionth of a second after the Big Bang — all matter of space, everything, was squeezed down to less than the size of the nucleus of a hydrogen atom (which is around a trillionth of a centimetre across) and the temperature was one billion, billion, billion degrees.

Inflation

A little later, around 10^{-34} seconds, or one ten billion, trillion, trillionth of a second after the Big Bang, a major event in the history of the Universe

Stars are formed when huge interstellar clouds of dust and gas collapse under the influence of their own gravity.

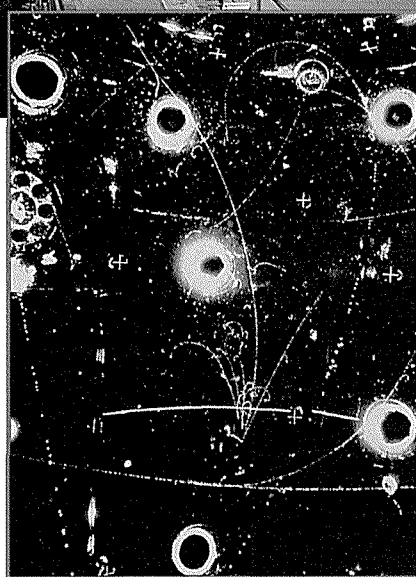


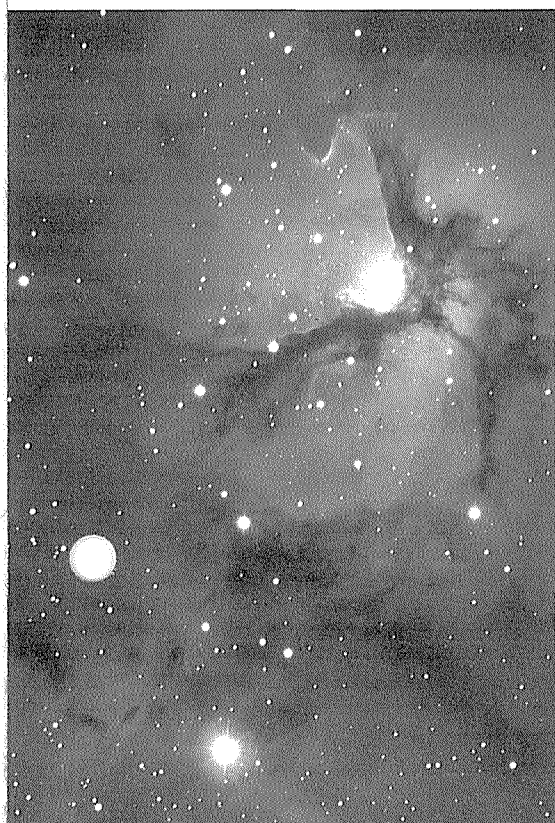
PHOTO CERN

occurred — it suddenly inflated to around 10 cm across. At this point, a flood of particles were created which would eventually form atoms. (These were the basic building blocks of the matter we know today). There were also neutrinos, which are ghostlike particles that can pass through the Earth as if it did not exist.

Atom-building began when the Universe was around a second old and had cooled to a mere 10 billion degrees. Over the next three minutes or so, the nuclei of the lightest elements — hydrogen, helium and lithium — were created.

For the next 300,000 years, as the Universe continued to expand, light and other electro-magnetic radiation dominated. But when the temperature dropped to around 10,000 degrees and the matter thinned out, electrons were captured by nuclei atoms. With no free electrons to

Spectrum Colour Library



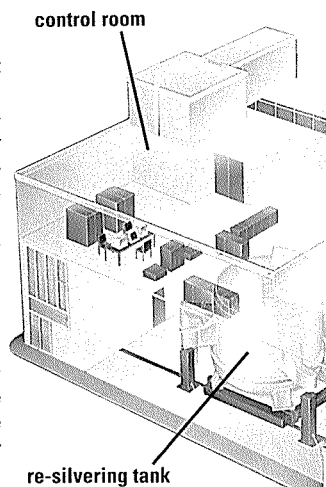
interact with the radiation, the Universe suddenly became transparent. But as it was only a huge, expanding cloud of thin, hot gas there was not much to see.

As the Universe continued to expand it cooled and grew dark. Gradually the huge cloud began to break up. Bits of it began to contract under the influence of their own gravity. 'Small' clouds began to condense into what would one day become stars and galaxies. As these clouds collapsed further, the pressure built up at their centres increased and set off nuclear reactions. These gave off light and the first stars began to illuminate the heavens.

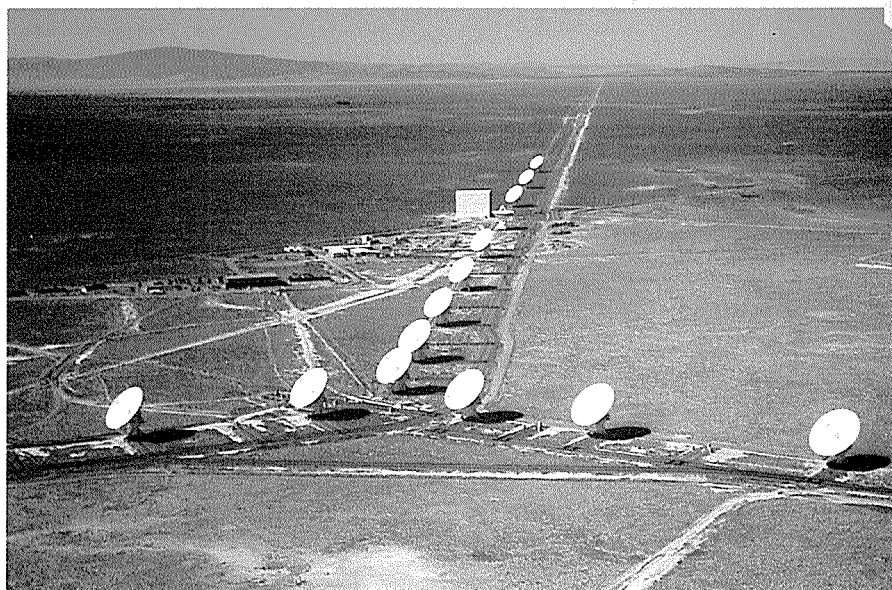
Black holes

Stars are still being born today. The more massive ones – 10 or more times the mass of our Sun – age rapidly and explode after only a few million years. Some leave behind a tiny, dense remnant, a neutron star, perhaps 10 km across but of 10 trillion times as dense as lead. Others leave a remnant that is so dense its massive gravity prevents

Large reflecting telescopes like the William Herschel Telescope on the Canary Islands observe the galaxies speeding away from each other.



Radio telescopes can see out towards the edge of the Universe – and back to almost the beginning of time.



planets and the interstellar gas will have vanished and black holes will be almost the only matter remaining.

These black holes will themselves 'evaporate', giving out immense quantities of energy in the process. The most massive black holes – those the size of an entire galaxy – will take a million trillion trillion trillion trillion years to disappear. Then the Universe will be a featureless sea of tiny particles and electromagnetic radiation all speeding away from each other at immense speeds. Time will slow to a halt.

even light escaping. This is a black hole.

Our Sun will live for about 10 billion years. But towards the end of its lifetime it will expand to engulf the planet Mercury, then contract, cool and slowly fade to darkness.

Scientists are not sure whether the Universe will continue expanding for ever. The matter we can see in galaxies is not enough to halt the expansion by gravity alone. But it is thought that there may be a lot of 'dark' matter, so far undiscovered – the only things we can really see in the heavens are stars that give off light. The gravitational pull of this dark matter could halt the expansion. If it did, the Universe would collapse back to a single point in a 'Big Crunch'. In the Big Crunch, time would end.

If there is no 'dark' matter and the

Universe does not collapse, it will go on expanding forever, spreading its contents over ever increasing distances. A hundred billion years from now, the cluster of galaxies will have broken up, though stars will still be forming in individual galaxies. It will not be until a hundred trillion years from now that the last stars will fade into darkness.

After 10 million trillion years, the galaxies will have disappeared as most of their long-dark stars will have escaped from them. Some 10 per cent of stars will have fallen into the black holes.

Death of matter

Matter itself will begin to die and, over 10 million trillion trillion years, will break down into smaller particles and electromagnetic radiation. By then the dead hulks of stars,

Just amazing!

LIGHTNING SPEED

LIGHT TRAVELS AT 300,000 KM A SECOND – OVER ONE BILLION KM AN HOUR. IN ONE SECOND, A LIGHT BEAM COULD TRAVEL ROUND THE EARTH SEVEN TIMES.



Paul Raymond



SPACE FARMS
MOON COLONIES
BIOSPHERES

SCIENCE FICTION IS FULL OF 'cities in space' — giant space stations supporting people, plants and animals. Are such self-supporting cities on other planets feasible? Or what about a wheel-shaped space station growing crops and sending them back to Earth?

In theory, space has plenty of raw materials, and abundant energy from the Sun's light and other radiations. But could we use space-farms to grow crops and raise livestock? Once set up, a space-farm would need to become self-supporting — just like 'spaceship Earth'. The main difficulties could be starting it up and getting the balance right.

Solar energy

The idea of the space-farm has many attractions. We could grow only those plants and animals we wanted. Weeds, parasites, disease pests and wild animals that 'cash in' on the farmer's produce could all be left behind.

In space, the Sun shines brightly and continuously, giving out large amounts of energy which could be used by plants directly. Vast arrays of solar cells could turn sunlight into electricity, to power all the machinery on the farm.

But some crops need day and night, in order to go through their life cycles of germinating, growing, flowering and fruiting. Many animals, too, respond to the lengthening days of spring by coming into sexual condition ready to breed. These processes are controlled by daylight length. So too much sunlight might

ASTRO AGRICULTURE



A moon-farm would need a protective dome. Scientists have already created a prototype, Biosphere 2 in Arizona, USA, where fish and other animals were farmed and where crops were grown.



be harmful. To avoid this, computer-controlled mirrors could shine the light on certain areas at certain times, mimicking the days and nights of Earth. Or blinds might be drawn across the overhead dome of a Moon-farm.

Gravitational pull

Many plants become confused if grown without gravity. Their roots normally grow down and their shoots head upwards (this is called geotropism). Without gravity, the roots might head out of the soil while their leaves try to burrow underground. So the space-farm would need a gravitational field.

The Moon's gravity, at one-sixth of the Earth's, might do. But a floating space station would have to spin slowly to produce gravity – and make the farmers feel more at

Moon rock is very similar in make-up to rocks on Earth. The oxides in it can be turned into oxygen for breathing and water, while the silicon can be used to make glass and concrete. This would enable scientists (using solar power as a cheap form of energy) to cut the costs of building Moonfarms.



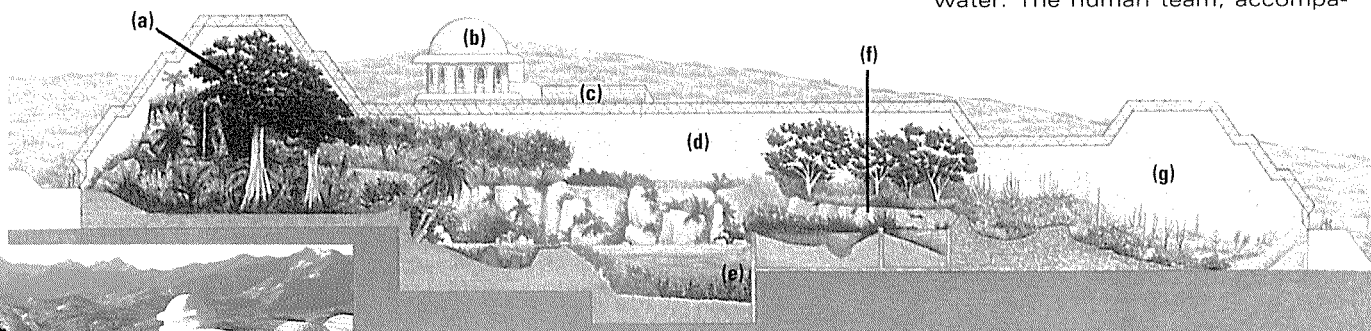
breathe, so they could refresh the air, just as they do on Earth.

It would cost a fortune to build space farms on Earth and then launch them. But the silicon in Moon rock can be used to make glass and concrete on the Moon,

tares (3.5 acres).

Four men and four women entered the building on September 26, 1991 and re-emerged exactly two years later. Biosphere 2 was designed to be completely sealed off from the outside world, so that it produced and recycled all its air and water. The human team, accompa-

NASA/SPL



Space Biospheres Ventures

Biosphere 2 contained seven 'biomes' – or types of environment. These are (a) tropical rainforest, (b) urban, where the residents will live, (c) an area for intensive agriculture, (d) savannah, (e) an 'ocean' ten metres deep, (f) marshland, and (g) desert.

nied by about 3,800 species of carefully selected plants and animals, grew their own food and recycled their own wastes. The only energy they received came, as in space, from the Sun.

Although a few emergency departures from the original objectives took place, such as the addition of oxygen when carbon dioxide levels twice rose dangerously high, Biosphere 2 still represented a beginning for the development of a space farm.

home!

Moon rocks are similar to the rocks on Earth. Both contain the same proportions of oxygen (60 per cent), silicon (17 per cent) and aluminium (8 per cent). So the Moon has one of life's great needs – oxygen – but not in the gaseous form we breathe. It is combined with other chemicals such as silicon (to make 'Moon-sand') and aluminium.

Moon water

Yet within two years of the first Apollo landing in 1969, scientists had shown that it was possible to produce both water and oxygen from lunar dust. Once enough water had been created, it could be recycled endlessly – just as on Earth.

The process of photosynthesis means that plants could convert carbon dioxide into oxygen for us to

saving up to 97 per cent of the launch costs.

Temperatures on the Moon vary from 120°C during the day to -170°C at night. A giant dome of plastic or glass would be vital to any space-farm. It would keep in the 'atmosphere' of gases and protect the inhabitants from cosmic and other harmful radiation, and from showers of tiny meteorites.

Heat-absorbing fluid could be circulated through tubes in the dome's walls, to absorb the Sun's heat. This heat could be used to generate electricity or to warm underground rocks, as a sort of 'heat reservoir'. Then in the ultra-freezing night the heat would be released to keep the farm warm.

A giant greenhouse-like building was built in the Arizona desert as a model for a future space-farm. Called Biosphere 2 (Biosphere 1 being the Earth itself), it covered 1.4 hec-

Just amazing!

FAT-FREE FAT

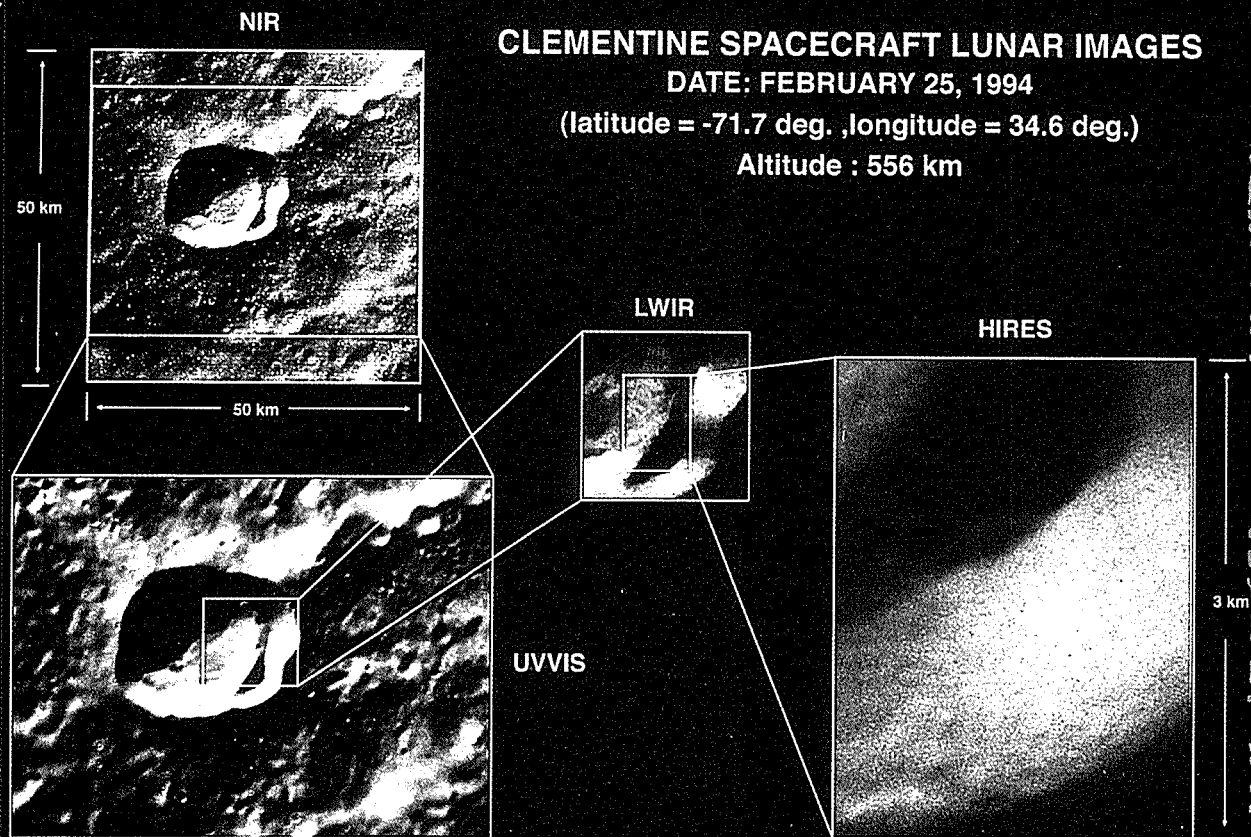
ONE AMERICAN COMPANY HAS DEVELOPED A FAT WHICH HAS NO CALORIES. IT IS MADE UP OF GIANT MOLECULES, WHICH CANNOT BE BROKEN DOWN AND PASS THROUGH THE BODY UNDIGESTED.



Paul Raymond



GLOBAL DEFENCE SYSTEM



A GLOBAL DEFENCE SYSTEM TO protect the Earth from being hit by a large asteroid has been proposed by scientists in the United States.

Such an impact, by an asteroid perhaps 10 kilometres across, is thought to have been responsible for the extinction of the dinosaurs — and, indeed, of more than half the species on Earth — at the end of the Cretaceous period, around 65 million years ago.

The risk of a similar catastrophic impact today, although slight, is by no means non-existent. Astronomers have estimated that there may be as many as 4000 near-Earth asteroids (NEAs — ones that regularly cross the Earth's orbit) more than 1 kilometre across, any one of which could cause widespread destruction. And in 1989 just such an object passed within 700,000 kilometres of the Earth — a hair's breadth on the astronomical scale of things! More recently, in 1908, a comet fragment approximately 100 metres across

struck Tunguska, in central Siberia. It exploded 8 kilometres above the ground with the force of a 12 megaton nuclear bomb. Everything within 30 kilometres was flattened. Fortunately, this is a remote area and no humans were killed.

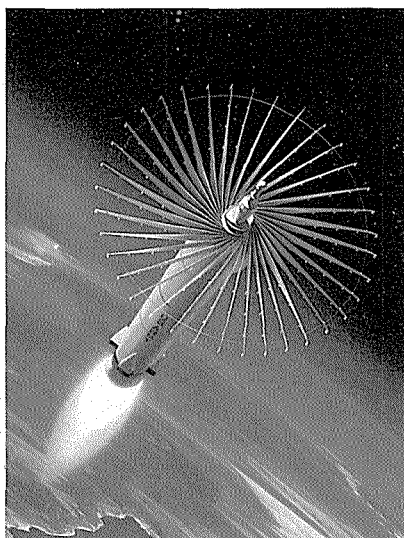
The US scientists have taken a two-tier approach. First, telescopes such as the 0.9 metre Spacewatch reflector on Kitt Peak, in Arizona, are scanning the sky for new NEAs, of which less than 200 are known, so that their orbits around the Sun can be calculated and the possibility of a collision assessed. In March 1994 the Kitt Peak telescope tracked a previously unknown 10 kilometre asteroid which skimmed past the Earth at a mere 160,000 kilometres. But it is of little use being able to predict a collision if we are able to do precious little about it.

The second tier of the US scientist's approach does intend to do something about it, namely to deflect the course of a threatening

Photos of the Moon's surface showing the massive craters created by asteroid impacts. It is hoped that new technology could avoid such catastrophic impacts on Earth.

asteroid or even blast it out of the sky using 'Star Wars' technology. Such a capability does not yet exist, but research into space weapons has been ongoing since 1984, when politicians first approved funding for the so called Strategic Defence Initiative (SDI). SDI, or 'Star Wars' as it became popularly known, was intended to provide a shield for the United States from potential Soviet nuclear attack by intercepting incoming intercontinental ballistic missiles using laser 'killer' satellites, 'kinetic energy weapons' (in which a collision would destroy both the weapon and the missile) and large orbiting mirrors that would reflect destructive laser beams fired from the ground on to their targets.

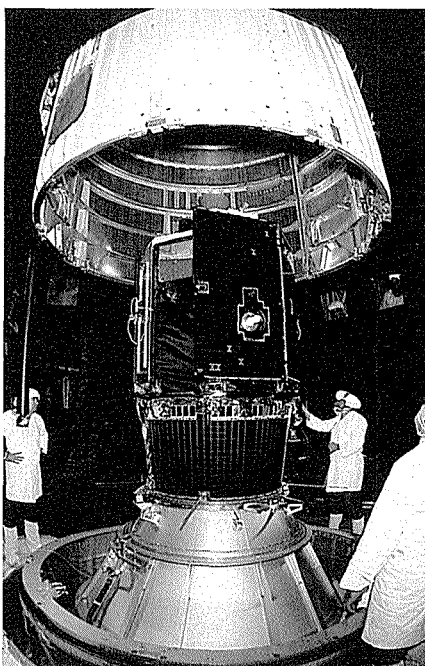




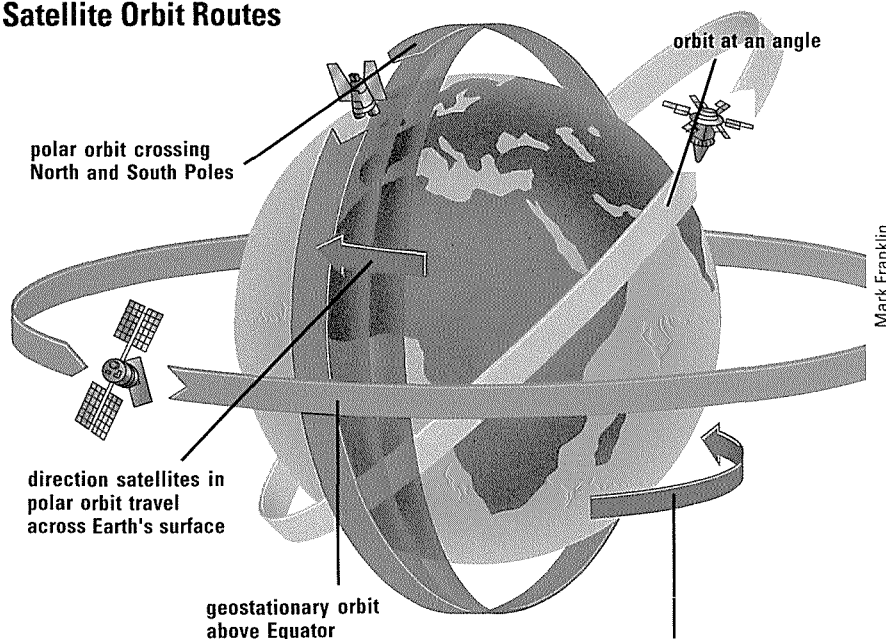
A 'Brilliant Pebble' missile destroys a hostile missile by crashing into it. To increase the chances of a collision, the fan-like structure opens out just before impact.

However, problems were encountered in trying to turn theoretical concepts into practical devices, and this coupled with a perceived lessening of the Soviet threat led politicians to reduce the SDI budget. SDI became GPALS (Global Protections Against Limited Strikes), in which the goal was to use 'kinetic energy weapons' launched from the ground, air or possibly space to destroy a few missiles fired at the United States, its overseas forces or one of its allies accidentally, or deliberately by terrorists. With the threat

The Clementine probe before its launch. The probe carries newly developed miniature sensors and lightweight components.



Satellite Orbit Routes



Satellites in geostationary orbit above the Equator take 24 hours to circle once and move east with the Earth, so they always stay above the same point on Earth. Those orbiting over the Poles, as the Earth below slowly turns, travel over most of the Earth's surface. Satellites orbit at an angle when launch sites, or the area to be covered, are too far from the Equator for geostationary orbit.

of further cutbacks in funding, 'Star Wars' scientists were eager to justify their research, and what better than to propose a global defence system to protect the Earth from possible asteroid impact?

In January 1994 *Clementine*, a satellite designed to test new lightweight components and sensors for tracking missiles in the Earth's atmosphere, was launched towards the Moon. It was to spend two months mapping the lunar surface,

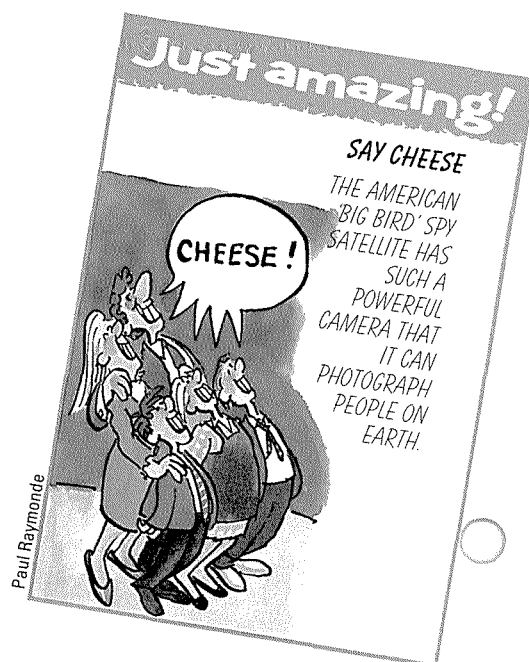
before proceeding to the 4x1.5 kilometre NEA Geographus, which it was to fly past at a distance of only 100 kilometres at the end of August.

Another satellite, *Near Earth Asteroid Rendezvous* (NEAR), is scheduled to be launched in February 1996. This is intended to encounter the 24 kilometre NEA Eros in December 1998 and to orbit it for a year, passing within 30 kilometres of its surface.

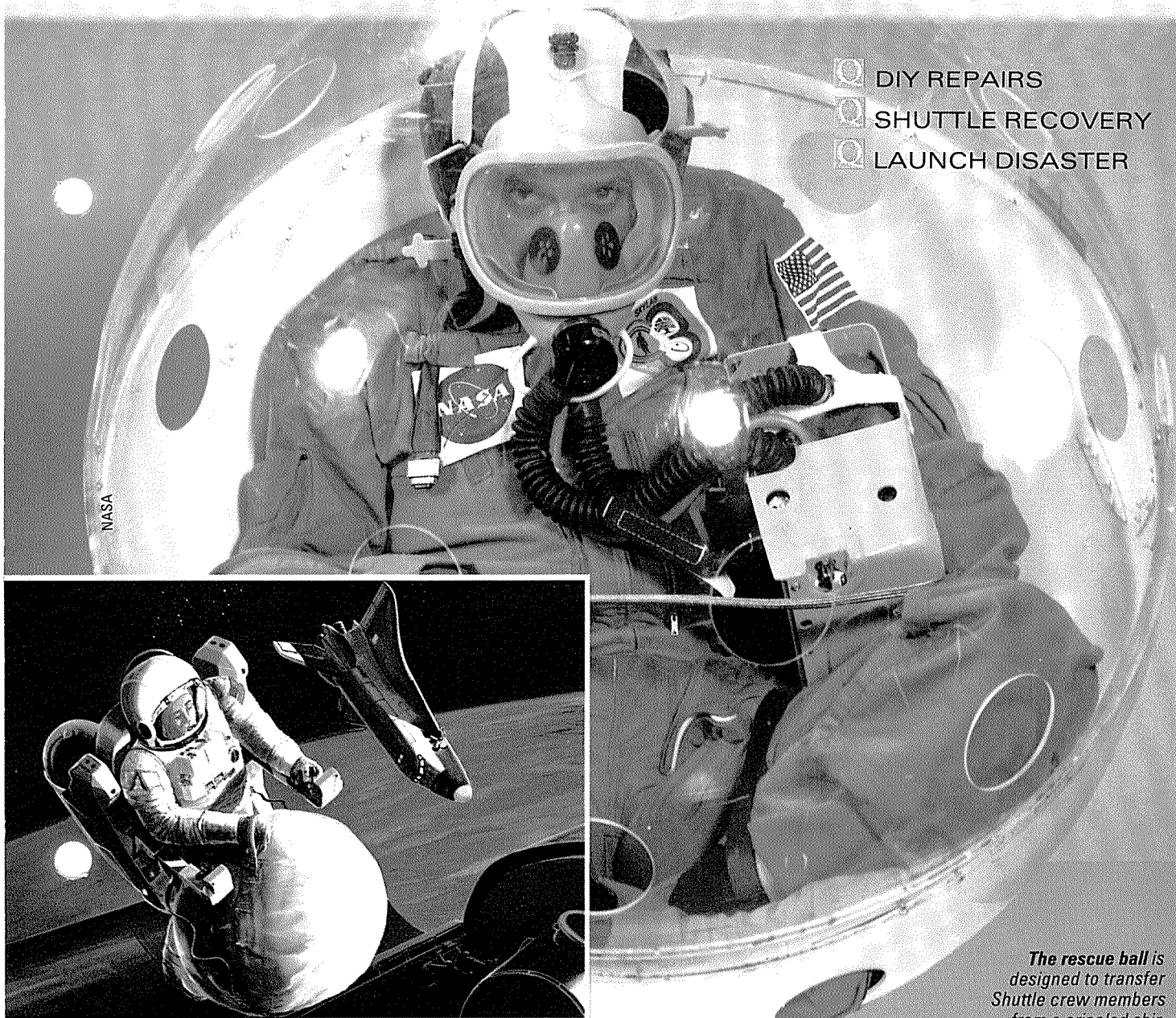
While the setting up of a global defence system probably lies some years away, the possibility of such a system and the interest aroused in asteroid impact has given the 'Star Wars' scientists another lease of life and has revitalized the astronomical study of NEAs.

BUGS IN SPACE

When planning a defence system, it must be a top priority to find out as much as possible about the enemy's defence and attack systems. ELINT (Electronic INTeelligence) satellites listen in to radio communications. For military purposes, the ability to eavesdrop on an opponent's radio links is very important because it gives a clear picture of what he intends to do in a particular situation. COMINT (COMMUNICATIONS INTeelligence) satellites pick up transmissions from radar stations. By listening to and recording radar transmissions, military planners can work out the location of enemy weapon systems and glean information on how they work.



- Q DIY REPAIRS
- Q SHUTTLE RECOVERY
- Q LAUNCH DISASTER



The rescue ball is designed to transfer Shuttle crew members from a crippled ship (inset).

SPACE RESCUE

HEADING FOR THE MOON, thousands of kilometres from Earth in a disabled ship, rescue is out of the question. How can the stranded astronauts be saved?

'OK, Houston, we've had a problem.' With these chilling words, Apollo 13 command module pilot Jack Swigert told NASA ground crew at mission control that his spacecraft was in deep trouble.

It was 9.09 p.m. on Monday, 13 April 1970. Apollo 13, with its crew of commander Jim Lovell, lunar module pilot Fred Haise, and Swigert, was 330,000 kilometres from Earth and bound for a third

manned landing on the Moon. Suddenly, the ship trembled and the astronauts heard a loud bang. Though no-one knew it at the time, an oxygen tank in the service module had exploded, ripping off a side panel completely and severing a vital fuel line to the command module in which the astronauts lay.

The lunar module

Almost immediately, the Moon landing was cancelled. All efforts were focused instead on simply trying to save the astronauts' lives. With its main fuel supply cut off, the command module would quickly

run out of power. The only option left was for the crew to crawl into the lunar module, called Aquarius, and use it as a kind of lifeboat in which to return to Earth. Unfortunately, Aquarius was only designed to support two men for up to two days. Now it would have to keep alive a crew of three for the four-day journey home.

Conserving water

Air, water, and electricity were rationed to the bare minimum. As a result, the cabin temperature gradually fell to just a few degrees above freezing. Resting in shifts,



the astronauts used the command module as their 'upstairs bedroom', although it was so chilly they could hardly sleep. To conserve water, each man was allowed only half a litre a day – one fifth the normal amount.

One of the most tense moments

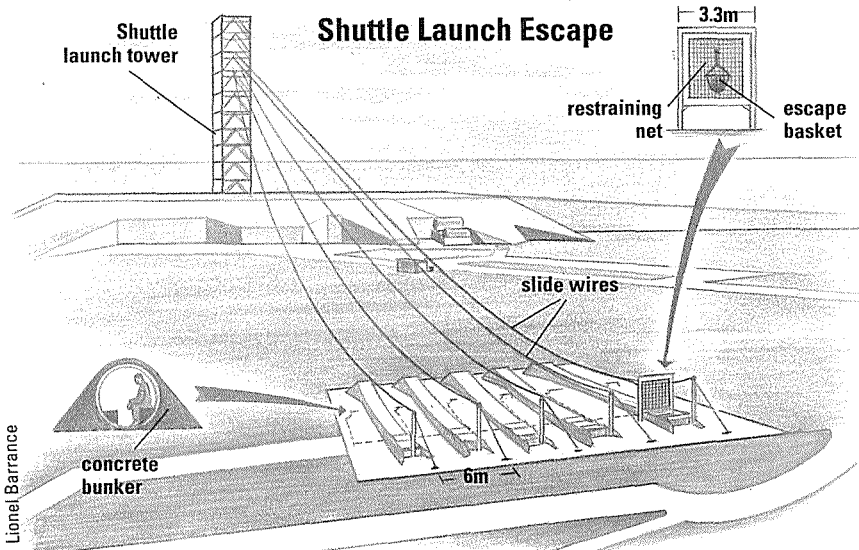
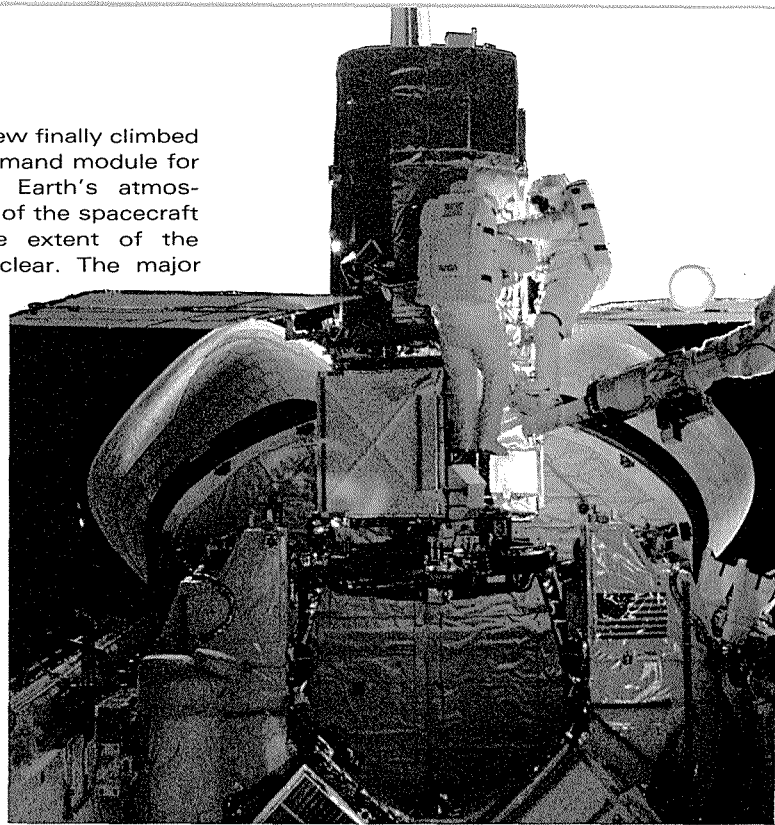
LAUNCHPAD DISASTER

On 28 January 1986, the Shuttle orbiter Challenger was launched for the tenth time. But 73 seconds into the flight the accelerating Shuttle suddenly exploded and was blown apart. The crew of seven – astronauts Dick Scobee, Mike Smith, Judy Resnik, Ron McNair, Ellison Onizuka, Greg Jarvis, and teacher Christa McAuliffe – all perished in the worst space disaster ever. The cause of the explosion was a leaking joint in one of the booster rockets. As a result of the disaster, many modifications were made to the Shuttle, and flights did not resume until September 1988.

came when the crew finally climbed back into the command module for re-entry into the Earth's atmosphere. As the rest of the spacecraft was cast-off, the extent of the damage became clear. The major

Astronauts George Nelson and James van Hoften use the Shuttle's Remote Manipulator System to help them repair the rescued Solar Maximum Mission Satellite.

In an emergency, Shuttle crew members can escape by sliding down cables in a metal basket to reinforced ground bunkers 400 metres from the base of the tower.



dioxide they were breathing out, because the lunar module's air system was overloaded. In desperation, they taped hoses from a Moon-suit to a plastic bag which they then fitted tightly around the command module's air filter to create an atmospheric 'scrubber'.

Space station

In June 1985, two Russian cosmonauts blasted off on a mission to revive the orbiting Salyut-7 Space station that had frozen up because of an instrument failure. The two men, who were specialists in Space repair work, had to dock their ship manually since the lack of power aboard the station ruled out an automatic link-up. They then set about recharging Salyut-7's dead batteries, warming up the Space station, and replacing electronic equipment that had been damaged.

concern now was whether the explosion had also damaged the heat shield at the back of the command module. Luckily, it had not. On 17 April, Apollo 13 splashed down safely in the Pacific Ocean.

The incredible adventure of Apollo 13 and the later tragedy of the Challenger disaster underline how hazardous space flight can be.

However, in the Shuttle era, orbiting astronauts stand a better chance of being rescued in an emergency. This is because there is usually a Shuttle on the launch pad most of the time being prepared for lift-off. And it could be switched to a rescue mission with the minimum of delay.

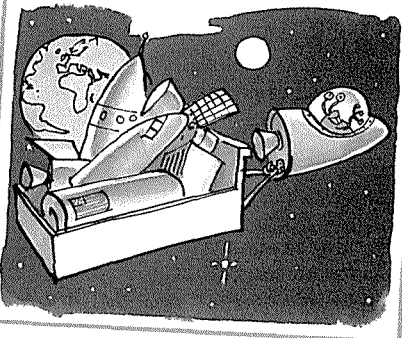
Suffocating

When equipment fails in Space it is up to the crew, with advice from mission control, to try to repair it or to rig up some makeshift apparatus in its place. The Apollo 13 astronauts, for instance, faced the prospect of suffocating on the carbon

Just amazing!

SPACE JUNK

LITTERED WITH OVER 7,000 HI-TECH OBJECTS, FROM OLD SATELLITES TO BURNT-OUT ROCKETS, EARTH ORBIT THREATENS TO BECOME A DANGEROUS OBSTACLE COURSE.



Paul Raymonde

The docking procedure used during the Lunar-landing missions would be the mainstay of any rescue of a stranded spacecraft.

NASA/Science Photo Library

SPACE ODYSSEY

Voyager 2 passed Neptune at the end of August 1989 after a 12 year journey. The Space probe visited Jupiter, Saturn and Uranus before reaching Neptune.

Seth Shostak Science Photo Library

AT THE EDGE OF THE SOLAR System, far from the Sun, lies the planet Neptune, too faint to see from Earth with the unaided eye. In August 1989 the US Space probe Voyager 2 flew over the cloud tops of Neptune at a distance of only 5000 km radioing back pictures to scientists on Earth.

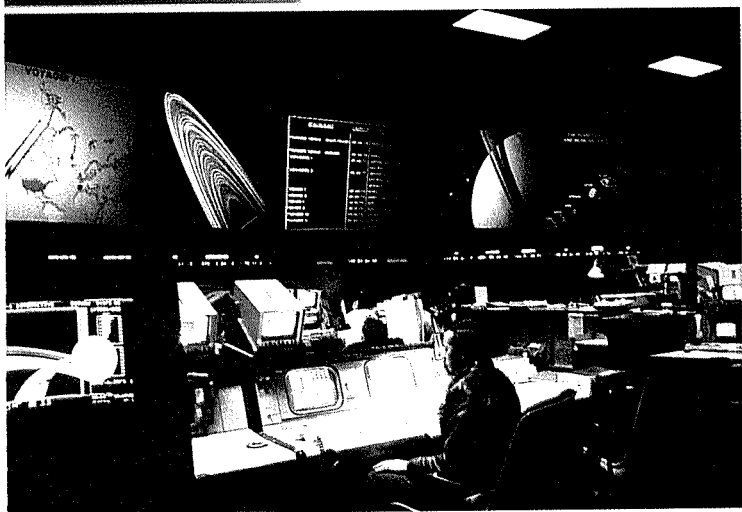
These pictures revealed the planet to be a blue-green ball of gas surrounded by thin rings of debris and a family of eight moons, only two of which had previously been seen from Earth. Among Neptune's clouds is a great dark spot the size of Earth plus bright, high, cirrus clouds of frozen methane.



Icy volcanoes

The surface of Neptune's largest moon, Triton, is covered in pink ice with jumbled ridges and grooves. Perhaps the greatest surprise is signs of ice volcanoes on Triton, fed by underground pools of liquid nitrogen that erupt on to the surface of this frozen world.

*Mission control
NASA's Jet
Propulsion
Laboratory
California
Voyager
encountered
Saturn
G...e*



The Neptune encounter completed a remarkable 7-billion-km odyssey that had begun 12 years earlier with the launch of Voyager 2 and its identical sister ship Voyager 1 from Cape Canaveral in Florida. Each Voyager craft's most obvious features are a radio dish measuring 3.7 metres across, through which it sends information back to Earth, and a 13-metre-long arm on which are mounted instruments to detect weak magnetic fields. This long arm keeps the instruments away from the magnetic field of the spacecraft itself.

TV cameras

Instruments for studying the planets, including two TV cameras for taking wide-angle and telephoto pictures, are on a shorter arm. A third arm holds the spacecraft's power supply, which converts heat from the radioactive decay of plutonium into electricity. Travelling far from the Sun, the Voyagers cannot use energy from sunlight to provide electricity.

The probes' first target was giant Jupiter, largest of the nine planets in the Solar System. Jupiter is enveloped in storm-tossed clouds that are drawn out into belts as the planet rapidly rotates. Beneath the clouds are seas of liquid hydrogen. Jupiter, like the other outer planets visited by the Voyagers, has no solid surface, so we could never land there.



NASA Science Photo Library

It would be dangerous to approach too close to Jupiter, since it has a strong magnetic field that traps atomic particles. As the Voyagers passed Jupiter they were bathed in radiation one thousand times the lethal dose for humans.

Jupiter has spectacular and colourful clouds, tinted yellow and red by chemicals. The Voyager cameras

The American flag and a special record entitled Sounds of the Earth were stored aboard Voyager 2 as evidence of life on Earth, in case Voyager meets life elsewhere. The record contains greetings in 60 languages, music, the sound of the wind, animal noises and electronically imprinted words and photographs.



ZEFA

Television cameras aboard both Voyager spacecraft took high-resolution photographs of the atmosphere and features of each planet encountered.

zoomed in on an eye-shaped storm cloud, the Great Red Spot, large enough to swallow three Earths.

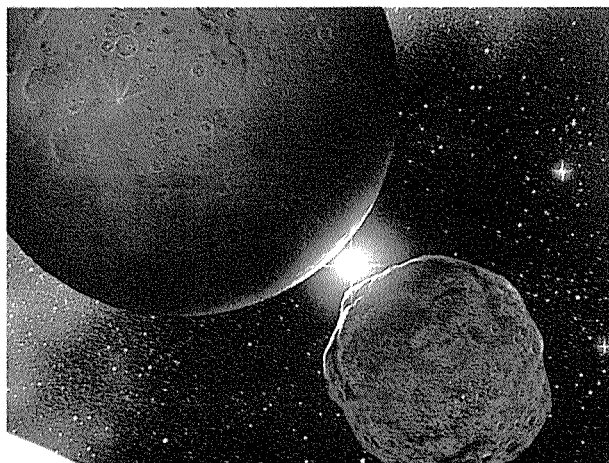
Orange moon

Jupiter's two largest moons, Ganymede and Callisto, are cratered by the impacts of meteorites, while another moon, Europa, has a smooth, icy surface veined by cracks. Most spectacular is the moon Io, the surface of which is covered with orange sulphur. Fountains of liquid sulphur erupt from Io's interior as if the moon were slowly turning itself inside out.

Saturn's rings

From Jupiter, the Voyagers travelled to Saturn, perhaps the most beautiful planet in the Solar System because of the bright rings that girdle its equator. These are composed of countless tiny ice-covered rocks – possibly the building blocks of a moon that never formed. In close-up, the rings of Saturn were seen to consist of thousands of threadlike

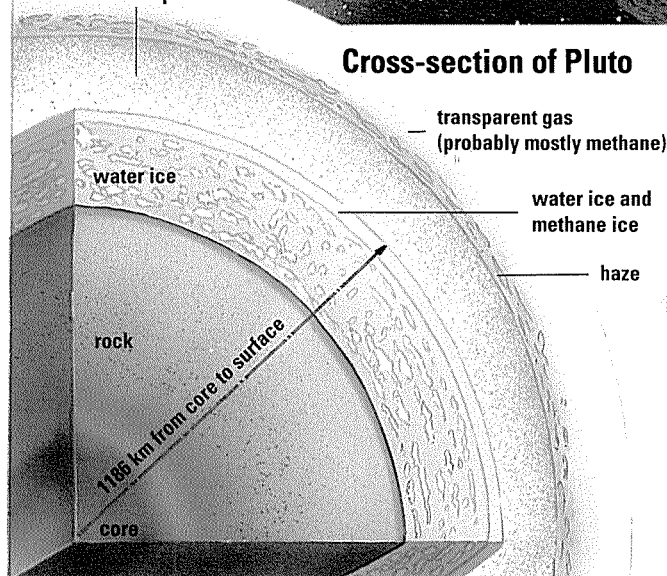
Pluto, the most distant planet from the Sun yet discovered, was first spotted in 1930, and Pluto's moon Charon was only discovered as recently as 1978. Charon, 19,640 km from Pluto, is half as big across as Pluto itself; some scientists have even described the two as a 'double planet'.



David A Hardy/ Science Photo Library

Frozen nitrogen and carbon compounds

Cross-section of Pluto

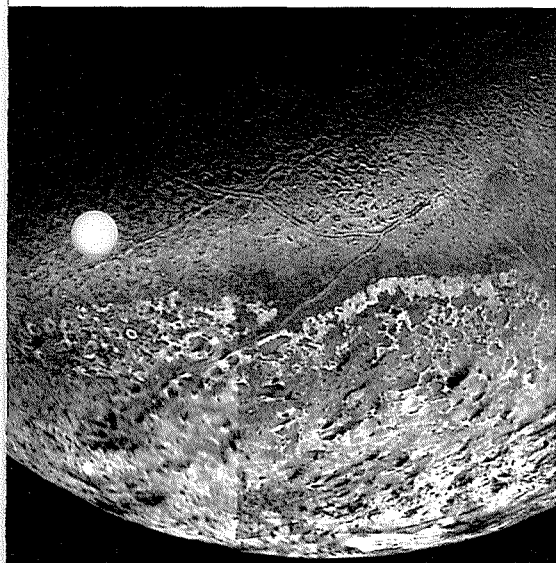
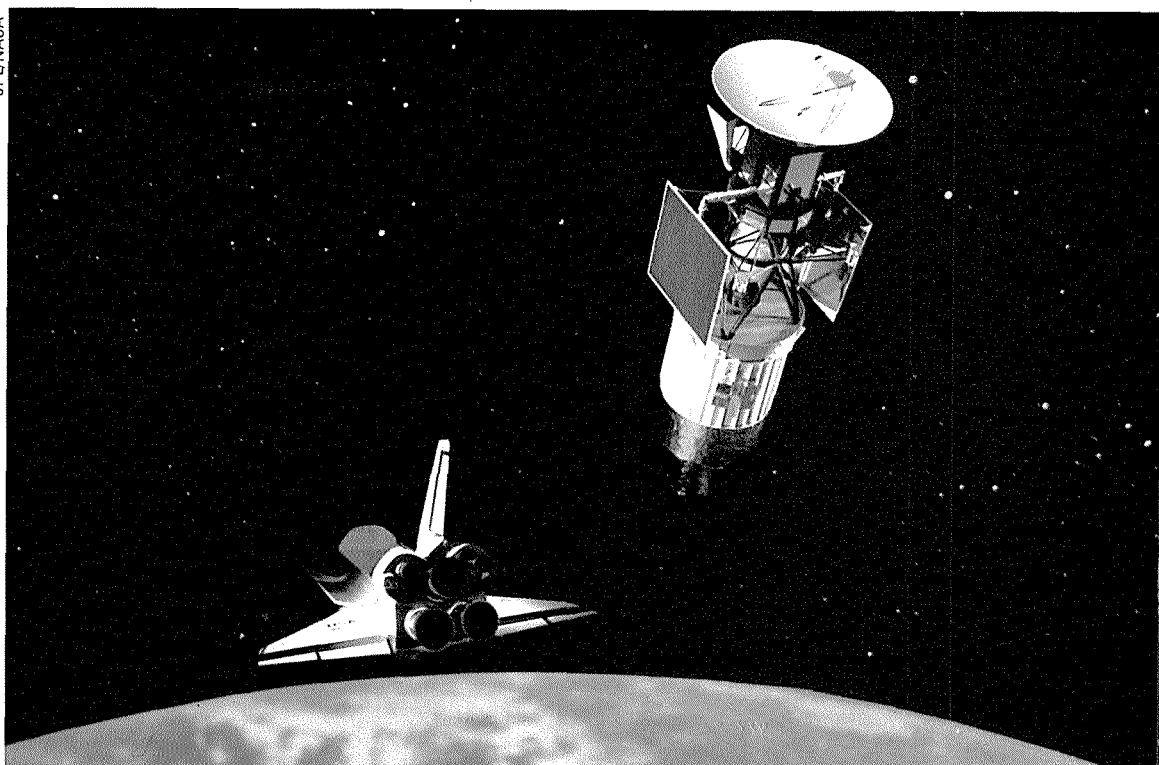


The only planet in our Solar System that has not been visited by a Space probe from Earth is Pluto. Astronomers observing the planet from Earth have calculated that Pluto is almost twice as dense as water. It was first thought that Pluto was made of solid methane, but methane has too low a density, so scientists now believe Pluto must be largely rock.

Magellan was carried into Space in the cargo bay of Space Shuttle Atlantis in May 1989. The probe then left the Shuttle to begin its 15-month journey to Venus. Magellan mapped Venus's surface using radar and recorded features as small as 10 km across.

Voyager 2's cameras took more than 9,000 pictures of Neptune and its largest moon, Triton (below), in August 1989 and transmitted them 4.5 billion km to Earth. Scientists learnt far more from these images than they could using telescopes.

JPL/NASA



JPL/NASA

ringlets, resembling the surface of a long-playing record.

The Voyagers also discovered several new moons, as they did at every planet they visited. Saturn itself, although similar in composition to Jupiter, has less colourful clouds, because high-altitude haze masks the cloud features from view.



On to Titan

Saturn's largest moon, Titan, is wrapped in a smoggy atmosphere of nitrogen – the main constituent of the Earth's atmosphere. Titan possesses simple organic compounds that might have evolved into life had Titan, at nearly ten times Earth's distance from the Sun, not been so cold.

After passing Titan, Voyager 1's path was bent upwards and away from the plane in which the planets orbit the Sun. But Voyager 2, which did not pass so close to Titan, was put on course for the next planet, Uranus, which it reached at the beginning of 1986.



Fifteen moons

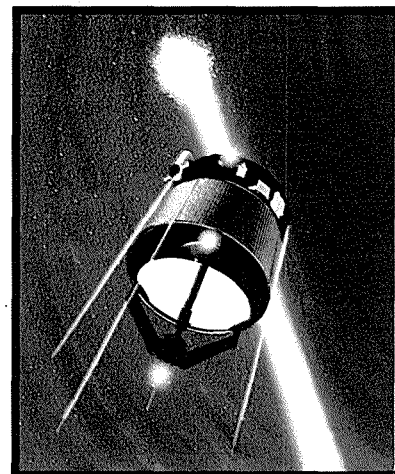
Following the excitement of Jupiter and Saturn, Uranus looks bland, being a virtually featureless, blue-green ball. Main scientific interest focused on its rings (known from Earth but never seen in detail before) and its moons, of which Voyager 2 discovered ten to add to the five already known. Most astounding of all is the moon Miranda, which has a jumbled terrain that suggests it has broken apart and then reassembled at least once since its original formation.

By the time it reached Neptune, Voyager 2 was so far from Earth that its radio signals, even travelling at the speed of light, took over 4 hours to

reach us. Both Voyagers are now heading off into the Galaxy and controllers expect to be able to keep in touch with them until their signals become too faint to hear, in about the year 2020.

The success of Voyager 2 means that all the planets have now been visited by Space probes with the exception of tiny Pluto, which was not in the right position to be reached by either of the Voyagers. However,

PROBING A COMET

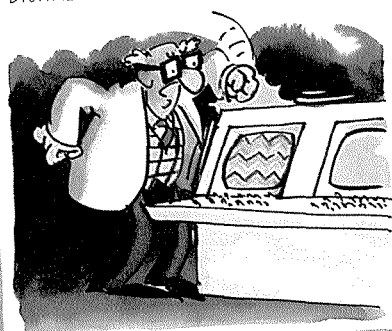


British Aerospace (Space Systems) Ltd

Just amazing!

CAN YOU HEAR ME?

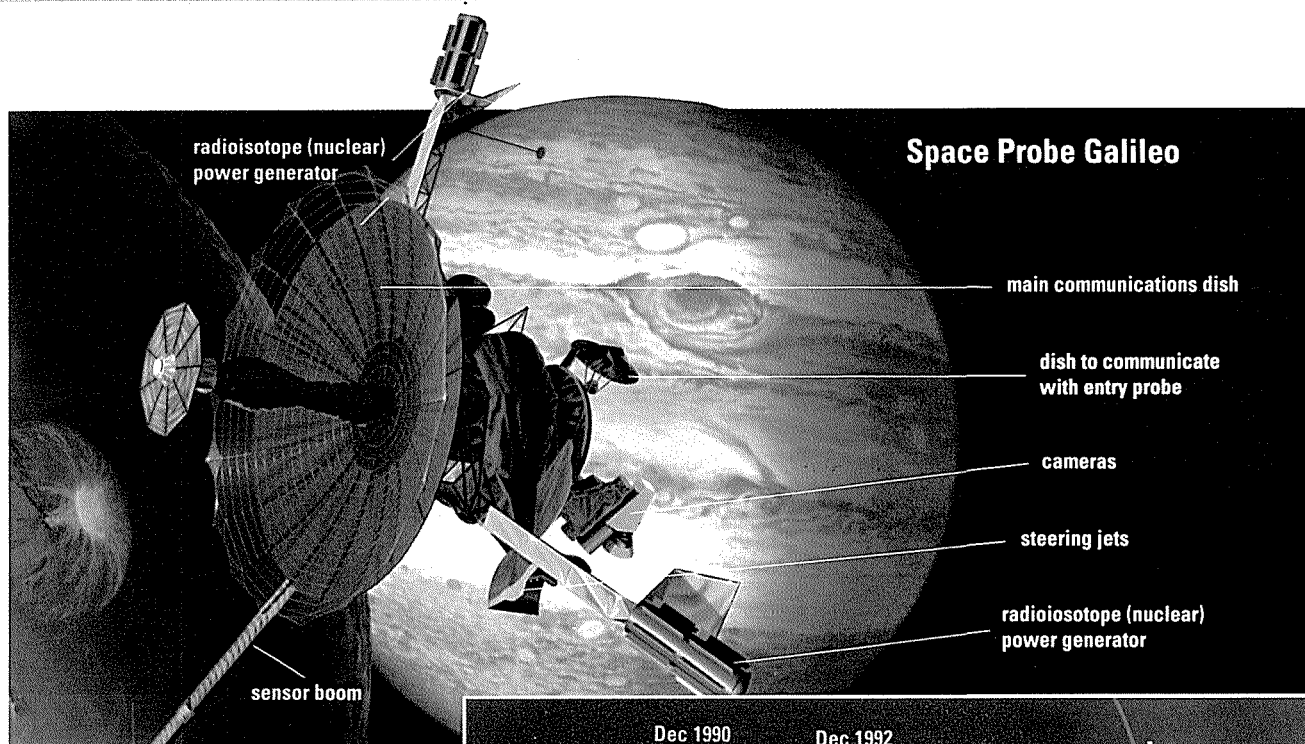
WHEN THE SIGNALS FROM VOYAGER 2 AT NEPTUNE REACHED THE EARTH, THEY WERE 20 BILLION TIMES WEAKER THAN THE BATTERY POWER THAT RUNS A DIGITAL WRISTWATCH.



Paul Raymond

The European Space Agency sent a probe called Giotto close to the head of Halley's Comet in March 1986, photographing the comet's nucleus, which is made of frozen dust and gas and measures about 10 km across. The nucleus has been likened to a huge dirty snowball. Dust and gas sprayed out from the nucleus form the comet's tail. Halley's Comet orbits around the Sun, passing close to Earth every 75 to 76 years; it will next return in 2061.



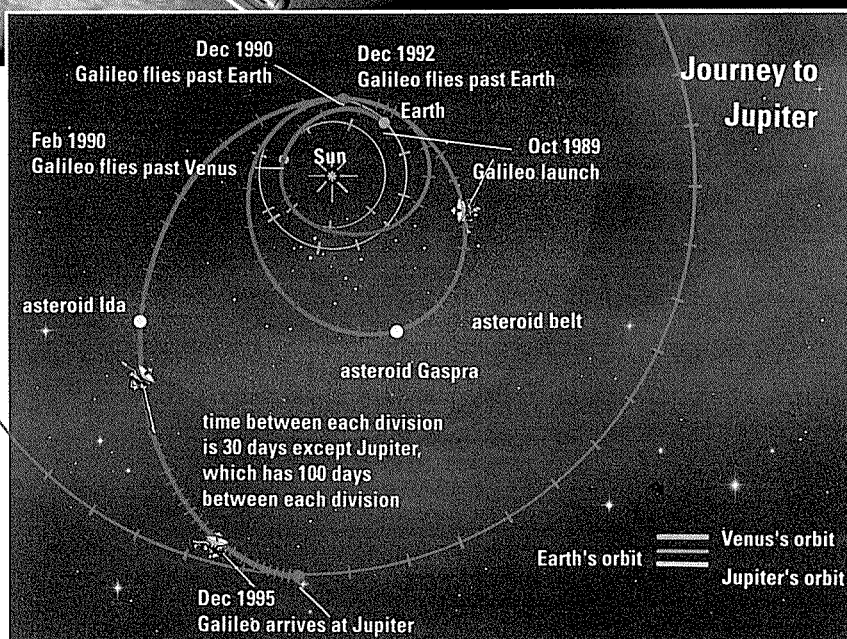


Unmanned spacecraft Galileo set off for Jupiter in October 1989. Rocket thrust and the gravitational pull of Jupiter's moon Io (shown behind the craft) will place Galileo into orbit around Jupiter – six years later. Rocket thrust also powered Galileo's break out of Earth orbit, but the probe must use the gravitational boost provided by the planets Earth and Venus to reach Jupiter.

Pluto is thought to resemble Neptune's moon Triton.

The first Space probe to reach another planet and send back information was the American Mariner 2, which passed Venus in December 1962. Venus, a planet whose surface is permanently shrouded by dense clouds of sulphuric acid, was found to be intensely hot, with a surface temperature of about 450°C.

Since then, the Soviet Union has landed probes on Venus and in May 1989 a new Venus probe, Magellan,



was launched by NASA from the Space Shuttle Atlantis. Magellan reached Venus in August 1990 and went into orbit around the planet, mapping its surface in detail by radar, which can 'see' through the clouds.

One question scientists hoped to answer was why Venus and Earth, although similar in size, have evolved so differently. They wanted to find out why Venus suffered a build up of gases that prevented heat from the Sun from radiating back into Space, trapping it in the planet's atmosphere, in the hope that this knowledge would help prevent a similar catastrophic 'greenhouse effect' from occurring on Earth.

Galileo to Jupiter

In October 1989, a probe called Galileo was launched to continue the exploration of Jupiter. It will reach Jupiter in a roundabout way, first flying past Venus in February 1990 and then looping twice past the Earth – the first time in December 1990 and then

again two years later. The rocket that powered Galileo's path away from Earth could not put it directly on course for Jupiter. Each planetary flyby speeded the Space probe up until it was moving quickly enough to reach Jupiter.

This complex flight path has its advantages, for Galileo was able to study Venus, Earth and the far side of our Moon on its way. It also photographed the asteroids Gaspra and Ida, which lie between Mars and Jupiter.



Death plunge

Galileo carries a small sub-probe that will plunge into the clouds of Jupiter, sending back information on atmospheric composition, pressure, temperature and winds for over an hour before it is destroyed. The main craft will go into orbit around Jupiter, monitoring the planet's weather and taking a close-up look at its main moons, including the sulphur volcanoes on Io. A similar probe, Cassini-Huygens, is planned for Saturn early in the 21st century.

LIFE ON MARS?

Mars was first flown by in July 1965, by American space probe Mariner 4. Two US probes called Viking landed on Mars in 1976 to look for signs of life, but found only a barren, rocky desert. The Viking probes did, however, discover that in the past the planet was both warmer and wetter than it is today – conditions in which life might have existed. Now, both the USA and Russia intend to find out more. Mars Surveyor, the US mission, consists of an orbiter to be launched in 1996 and a lander in 1998, while Russia's probes, Mars-96 and Mars-98, consist of both an orbiter and lander, also to be launched in 1996 and 1998.

RADIO TELESCOPES

COSMIC CLOUDS

ALIEN CIVILIZATIONS

LOOKING FOR LIFE

Our Galaxy, the Milky Way, viewed edge-on. It is a spiral system of gas, dust and more than 100,000 million stars.

ON AN ALIEN PLANET LIT BY the harsh glare of a strange sun a scientist turns a large radio dish towards the sky.

Hundreds – or even thousands – of years later those faint signals are picked up by another radio telescope on a planet orbiting a different star. The first interstellar message has been received across the light years of the Galaxy. The receiving civilization knows that it is not alone.

Such a scene may already have occurred. It could occur again one day soon – and ours could be the civilization on the receiving end.

Radio telescopes are so powerful that they can transmit a message to anywhere in our Solar System. Astronomers are already pointing radio-telescopes at stars in the hope of picking up radio messages, but as

yet no signals have been received. We may search many thousands more stars before we pick up a message – if there are any messages to be heard.

The chances of other civilizations like ourselves existing in Space are high. Our Galaxy alone contains at least 100,000 million stars. Even if only 10 per cent of these stars possess planets and if only a small fraction of all planets can support life, there could still be millions of places where life might exist.

Origins of life

What we do not know is how life begins. Biologists are still trying to piece together the first steps to life. Living things on Earth are made up of some of the most common substances in the Universe –

chemicals that contain carbon, hydrogen, nitrogen and oxygen.

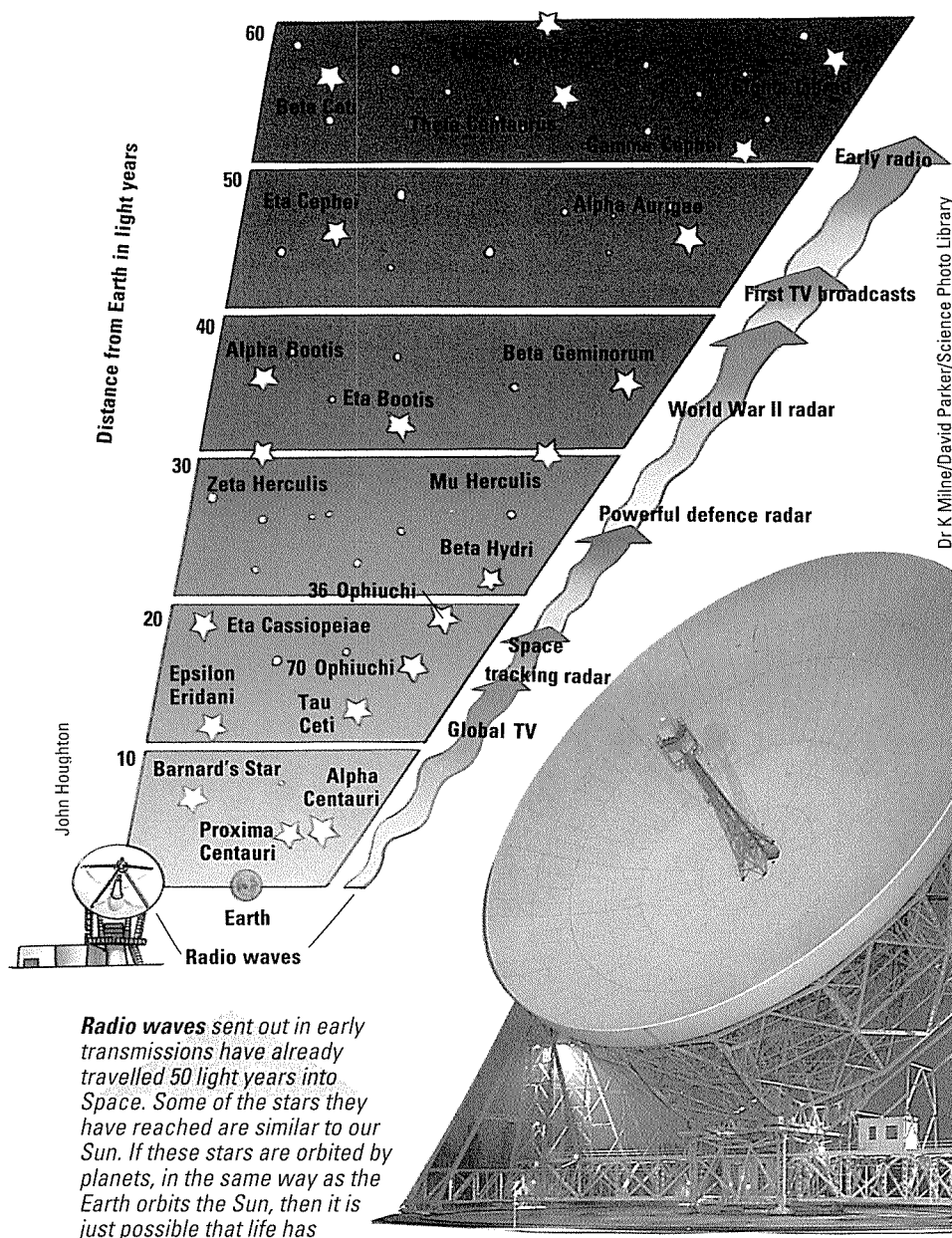
On Earth, these chemicals somehow assembled themselves into primitive plants over 3,000 million years ago. In the vast span of time since then more complex forms of life have evolved and the most intelligent beings – humans – are naturally asking questions about their environment in Space.

Galactic neighbours

Not all these steps will necessarily be repeated on other planets where life exists. In some places life may progress no further than simple plants, while dinosaurs may still dominate other worlds. But scientists estimate that as many as a million civilizations like ours could have developed in the galaxy! How many

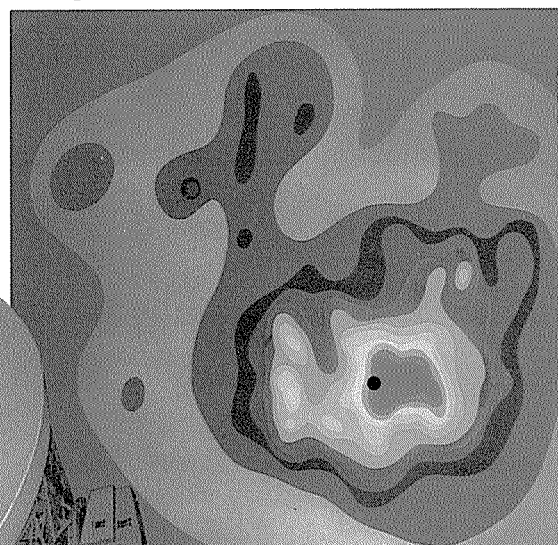


Making Waves In Space



nate that it is at just the right distance from the Sun for liquid water to exist. If it were closer to the Sun, it would be so hot that all the water would evaporate – as on Venus. If it were farther away, our planet would freeze. The most distant planets from the Sun – Jupiter, Saturn, Uranus, Neptune and Pluto – are unable to support life for this reason.

In 1976, two US Space probes, Viking 1 and 2, landed on the red



The pulsar (black dot) on this radio image represents the core of a star that exploded about 11,000 years ago. It spins 13 times per second, emitting light and radio waves. The coloured bands indicate emissions from the still expanding shell of gas and dust.

Radio waves sent out in early transmissions have already travelled 50 light years into Space. Some of the stars they have reached are similar to our Sun. If these stars are orbited by planets, in the same way as the Earth orbits the Sun, then it is just possible that life has evolved on them.

The Lovell Telescope in the UK captures astronomical radio waves in its 76-metre-diameter dish. The signals are amplified and filtered before being fed to the telescope's computer. Red lights on the focus box serve to warn low-flying aircraft.

of them are around today depends on how long each one lasts.

For example, if civilizations destroy themselves rapidly by nuclear war or pollution – as we may be in danger of doing – then there may be no one else around at present for us to communicate with. However if civilizations expand into Space, they may continue for very long periods of time. If so, the Galaxy could be teeming with advanced life-forms. Although, if that is the case, it is strange that as yet we have found no sign of them.

Our Earth is the third planet outwards from the Sun. We are fortunate

that it is at just the right distance from the Sun for liquid water to exist. If it were closer to the Sun, it would be so hot that all the water would evaporate – as on Venus. If it were farther away, our planet would freeze. The most distant planets from the Sun – Jupiter, Saturn, Uranus, Neptune and Pluto – are unable to support life for this reason.

Planetary systems

If we are to find life, therefore, it must be on planets going around other stars. At present, astronomers have still to confirm that other planetary systems do exist. The stars are so far away that a planet going around even the nearest of them is too faint to see directly through a telescope. However, astronomers have found that some nearby stars are wobbling slightly in position – apparently because one or more large planets are orbiting them.

Dust clouds

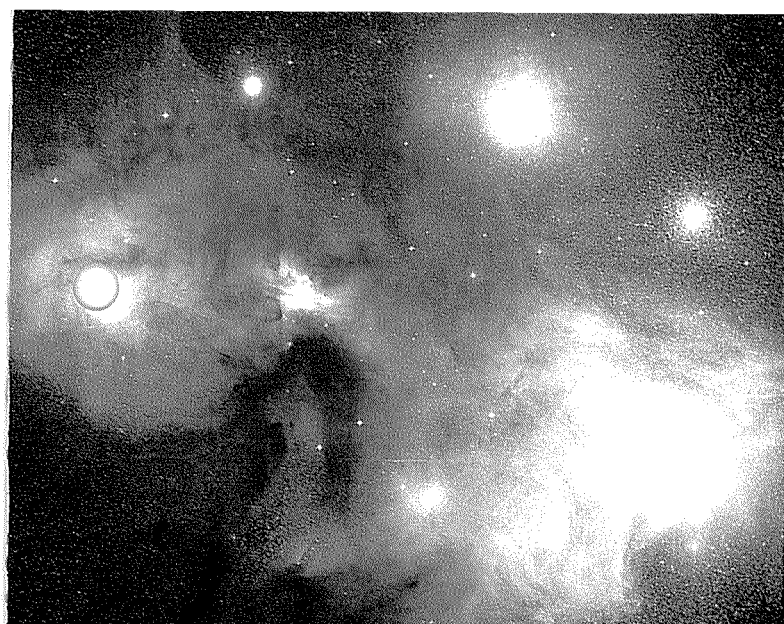
Perhaps the most impressive evidence for the existence of other planetary systems was found in 1983 when the Infra-Red Astronomy Satellite, IRAS, detected clouds of dust around more than 40 stars.

Just amazing!

POWER VISION

ACTING TOGETHER, THE EIGHT ANTENNAE OF THE AUSTRALIA TELESCOPE NETWORK ARE SO POWERFUL THAT THEY COULD BE USED TO READ THE PRINT OF A TELEPHONE DIRECTORY AT A DISTANCE OF 10KM.





The Scorpion – Ophiuchus nebula is one of the most colourful regions of the sky. Bright stars light up the surrounding clouds of gas and dust. To capture the contrasting colours of these clouds, astronomers at the UK Schmidt Telescope, in Australia, took three separate black and white photographs through different colour filters and combined them.

NORTHERN LIGHTS



ZEFA

Coloured lights in the night sky can be seen at high latitudes in both the northern and southern hemispheres. This photograph, taken above Lapp-land, is of the aurora borealis (also called the northern lights). Energetic particles from the Sun are attracted to the poles by the Earth's magnetic force. On entering the Earth's atmosphere they collide with air molecules, creating a halo of glowing light.

Royal Observatory, Edinburgh & Anglo-Australian Telescope Board

These clouds are thought to be planetary systems in the process of formation. One such cloud, around the star Beta Pictoris, was photographed in 1984. Our own planetary system is thought to have formed from such a cloud around the Sun 4,500 million years ago.

We cannot, as yet, travel to the stars as they are too far away, although scientific advances in the future may make some form of interstellar travel possible. But even if something similar to television's *Star Trek* does come true, it will still be easier to send radio signals between stars than to send people.



Pulsars

Radio signals travel at the speed of light, but since stars are so far apart it takes many years for a signal to travel from one star to another. In 1967, radio astronomers at Cambridge, UK,

thought they had stumbled across an alien transmission when they detected radio pulses coming from a small area of sky. What they had actually discovered was a pulsar – an exceptionally small and dense star that spins very rapidly, sending out radio pulses as it does so.



Receiving signals

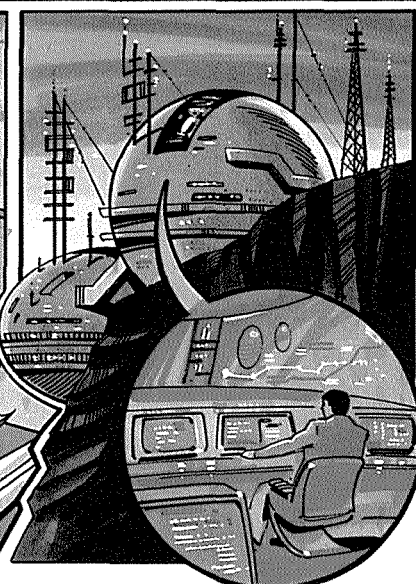
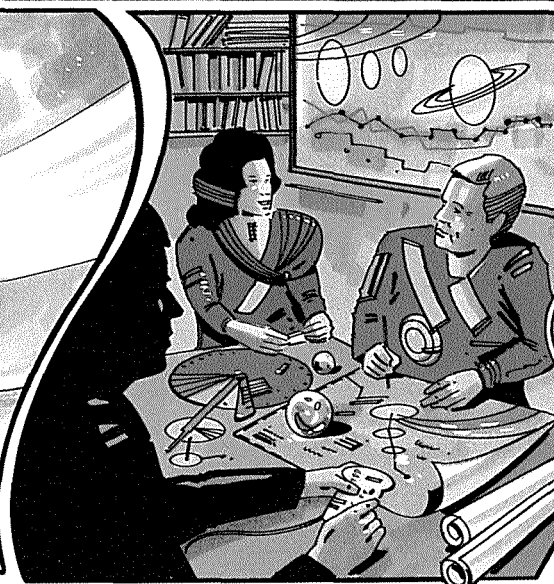
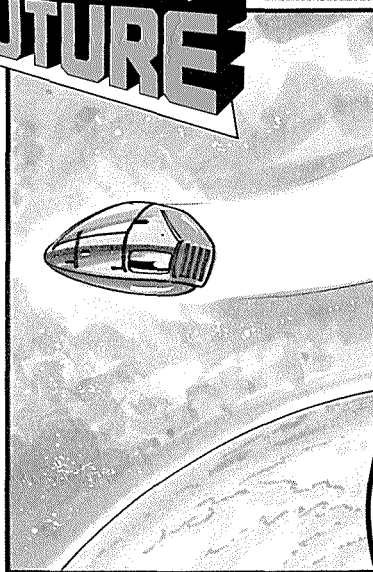
One clue to the fact that pulsars are natural objects is that they emitted at a wide range of frequencies. An artificial signal, as sent by a radio telescope, would be of one specific frequency – like that of a radio station emitting on a specific channel. However, there is an immense range of radio frequencies to choose from, which makes the task of finding any incoming signal very difficult.

Scientists in the United States have built receivers capable of tuning in to eight million channels at a

time. This helps to cut down the search time at each star, but there is still an immense number of stars to search for evidence that someone out there is signalling to us.

If we do hear a signal, it will most likely come in the form of a series of pulses that can be assembled into a picture. Pictures are easy ways of sending large amounts of information without the need for written language. Even if we could not understand an incoming message, its very existence would tell us what we have long hoped to find – that we are not the only civilization in Space.

INTO THE FUTURE



▲ Because the distances between stars and planets in Space are so vast, perhaps the only way to find life on other planets is by travelling through time.

▲ Time travellers would be like early Earth explorers – mapping new territories in both Space and time, to build up a picture of our Universe and perhaps those beyond.

▲ Advanced communications – capable of transmitting and receiving across the dimension of time – could keep explorers in touch with Earth in the present day.

Joe Lawrence

TRAVELLING THROUGH TIME





UFOs

Most sightings of Unidentified Flying Objects (UFOs) are cases of mistaken identity. Over 90 per cent of reports, when investigated, turn out to have been caused by natural or man-made objects. The main culprits include bright stars and planets, shooting stars, aeroplanes and orbiting satellites. Some cases are undoubtedly hoaxes. Despite careful investigation of UFO reports over many years, no alien spaceships have been scientifically identified.

Aetherius Society



Over 100,000 people claim to have seen UFOs in the last 30 years. There are reports from every country in the world – an average of 40 sightings per day. This photograph was taken in England in 1978.

Ella Louise Fortune/Fortean Picture Library



This detail is part of a larger photograph, taken in 1981, of a mountain on Vancouver Island in Canada. Neither the photographer nor her companions saw the UFO at the time. The UFO appeared later when the film was developed.

This UFO was photographed hovering over New Mexico in 1957.

Hannah McRoberts/Fortean Picture Library



Illinois Air-Traffic Control verified the presence of an unidentified object in the vicinity of several claimed sightings of this cylindrical object (an artist's impression) in the USA in 1987.

Julian Baum/Science Photo Library



Stephen Pratt/Fortean Picture Library

Robert Harding Picture Library

The reflection of a ceiling light on the inside of a window shows how easily a fake UFO picture might be produced.



A triad of UFOs captured on film in 1966. But experts are sceptical – the UFOs are out of focus, yet other details are clear.

A rare formation of lenticular (lens-shaped) clouds might explain this sighting.





MICROGRAVITY



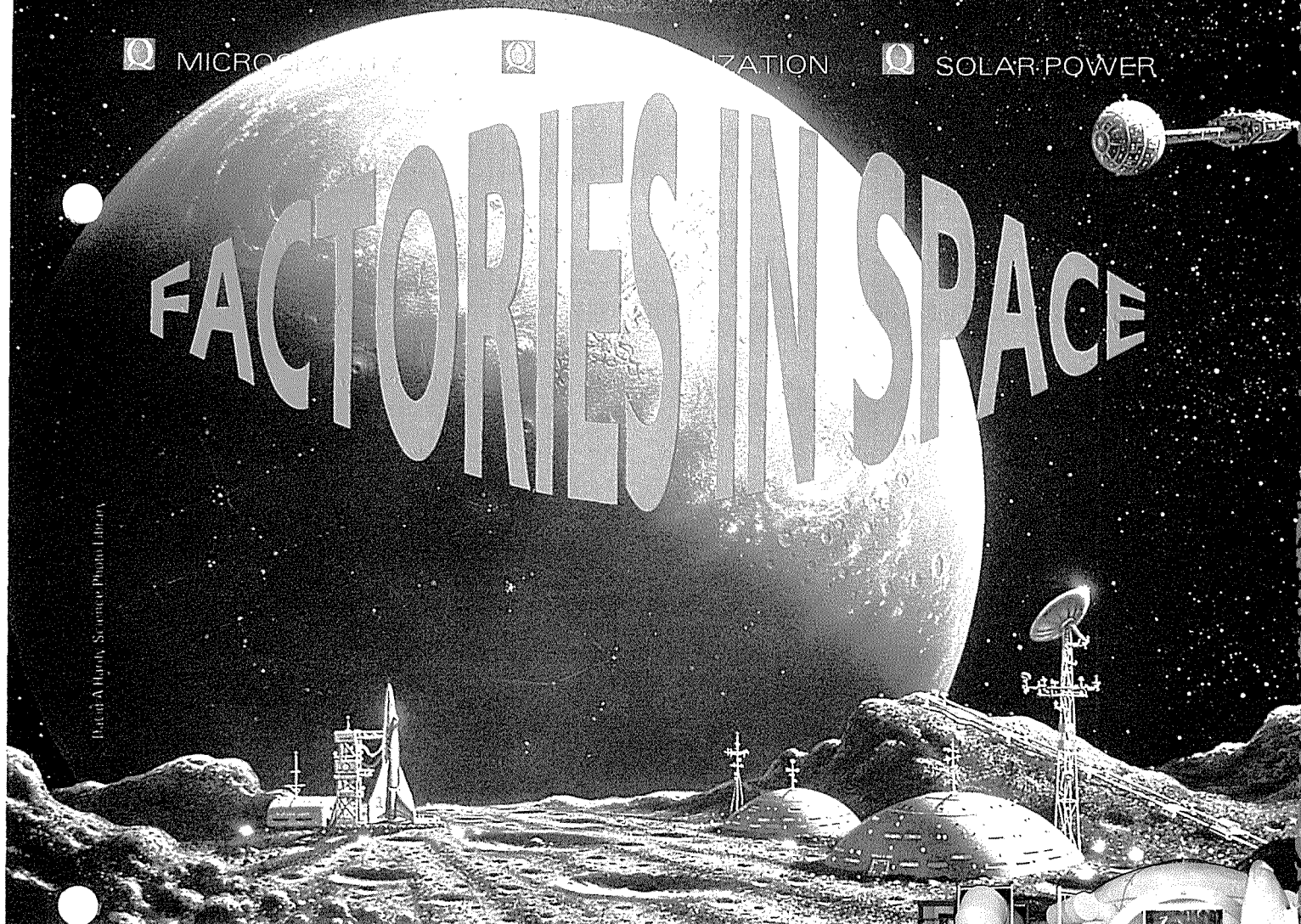
AUTOMATION



SOLAR POWER

FACTORIES IN SPACE

Data: A Hardy Science Photo Library



GIANT ORBITING FACTORIES could become a reality some time in the next century. Materials that are difficult or impossible to produce on Earth might be more easily manufactured in the near-weightless conditions of Space.

The reason why some scientists are looking to Space as a possible industrial base is because gravity interferes with certain manufacturing processes on Earth. It hinders, for instance, the thorough mixing of substances that have different weights because it tends to make heavier materials sink. Large, perfect crystals can also be hard to grow on Earth because of the effects of gravity. Orbiting factories may offer the ideal solution.

Free-fall

A spacecraft in orbit is actually falling all the time, but it falls at exactly the same rate as the Earth's surface curves away from it below. As a result, it never gets closer to the ground. Instead, the spacecraft and everything in it are in a perpetual state of free-fall and weightlessness.

Strictly speaking, there are slight gravitational forces present caused by changes in the spacecraft's motion. Scientists, therefore, use the

Space factories might one day be built on the Moon. Metals, such as aluminium, could be extracted from the lunar rock.

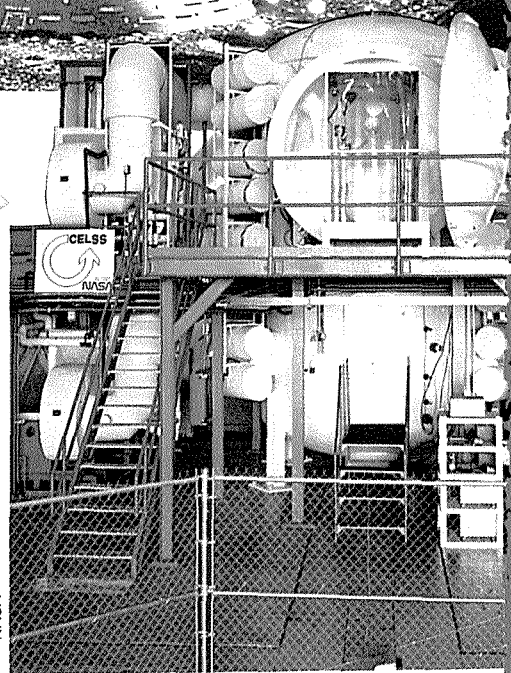
NASA is developing self-contained, life-support chambers for use as orbiting research laboratories.

term *microgravity* rather than zero-gravity to describe the conditions in an orbiting spacecraft.

To build the next generation of super-fast computers, scientists are experimenting with new substances that allow electricity to pass through them at high speed. These substances, such as gallium arsenide and mercury cadmium telluride, must first be crystallized in a very pure and uniform way. On Earth, however, gravity interferes with this process, causing the crystals to grow unevenly. In Space, as tests aboard the Space Shuttle have already shown, crystals grow bigger, purer—and faster.

Protein crystals

Other experiments, carried out during NASA's Shuttle flights, have involved growing various types of protein crystal. Proteins are highly complex substances vital to the functioning of the human body and all living organisms. If scientists knew more about them, this could help in



the development of new drugs for treating diseases such as cancer.

Orbiting factories might also be able to produce better quality audio and video tapes. This involves lining up the metal particles in the magnetic coating of the tape vertically rather than horizontally, thus increasing the recording density. Ball-bearings, and lenses are also greatly improved when manufactured in Space.

Carrying out research is one thing,



but developing a full-blown manufacturing industry in Space is another. Transporting materials to and from orbit is very expensive. And, in some cases, by the time an orbiting factory has been set up, industrial processing methods might have been improved on Earth. The American aerospace firm McDonnell Douglas, for instance, abandoned its research programme on the Shuttle

because of improvements in ground-based technology. Some companies, on the other hand, are now stepping up their experiments in microgravity.

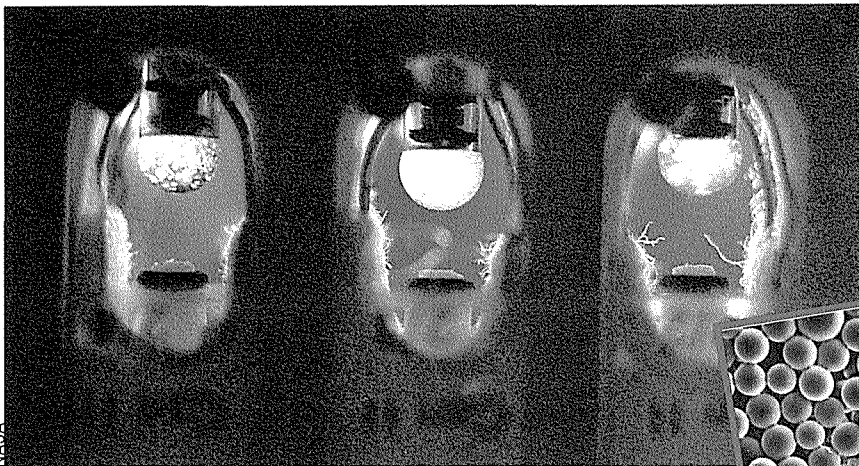
Much of the research into Space factories will be carried out in orbiting space stations, where astronauts will be able to conduct long-term experiments impossible to perform on short Shuttle flights.

The next stage is likely to be

TOYS IN SPACE

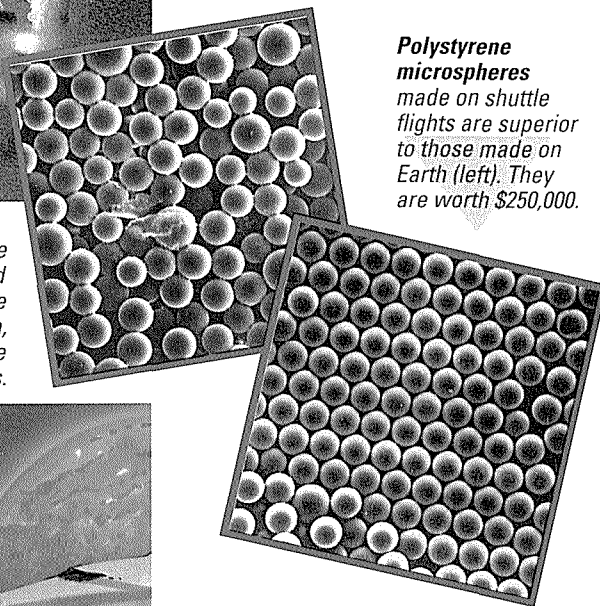
On 12 April 1985, the Space shuttle Discovery transported 11 familiar toys such as yo-yos, spinning tops and jacks into the weightlessness of space. The crew then experimented to see how the toys would behave in their new environment. A gyroscope, for example, kept on spinning much longer than on Earth because it did not lose energy through wobbling. Magnetic marbles proved interesting, too. They stuck together in floating chains that wiggled back and forth. When enough marbles were added, the two ends of the chain linked up to make a circle. A slinky, on the other hand, was unable to do its familiar 'walk' without the pull of gravity.

Polystyrene microspheres made on shuttle flights are superior to those made on Earth (left). They are worth \$250,000.



A lunar base would be built from prefabricated modules made on Earth. Living quarters would be situated underground to provide both radiation shielding and thermal insulation.

Protein crystals, grown in the weightless conditions on board the US Space Shuttle, are perfectly formed. On Earth, gravity causes defects in the size and shape of the crystals.



Lunar Factory

plant for processing moonrock

lunar shuttle

solar panels to supply colony with power

monorail

pressurized underground modules

the commencement of manufacturing certain materials on a small scale. Projecting even further into the future, orbiting solar power stations could provide the energy needed to run full scale manufacturing plants.

Just amazing!

POO!

SHUTTLE ASTRONAUTS HAD TO COPE WITH A NEW SPACE HAZARD - FLOATING RAT FOOD AND MONKEY DROPPINGS FROM THE CAGES OF ANIMALS UNDERGOING TESTS!



Joe Lawrence

Paul Raymonde

PLANETARIUMS

CONDENSING TIME

ELECTRONIC PROJECTORS

STARGAZING



American Museum-Hayden Planetarium

TAKE YOUR SEAT, LOOK UP, and you can see all the stars and planets in the night sky. In this case the sky is a smooth, domed ceiling and the stars are images created by a special projector. You are in a planetarium.

In just a few minutes, the planetarium projector can show motions that would otherwise take many hours, days, or even years to observe.

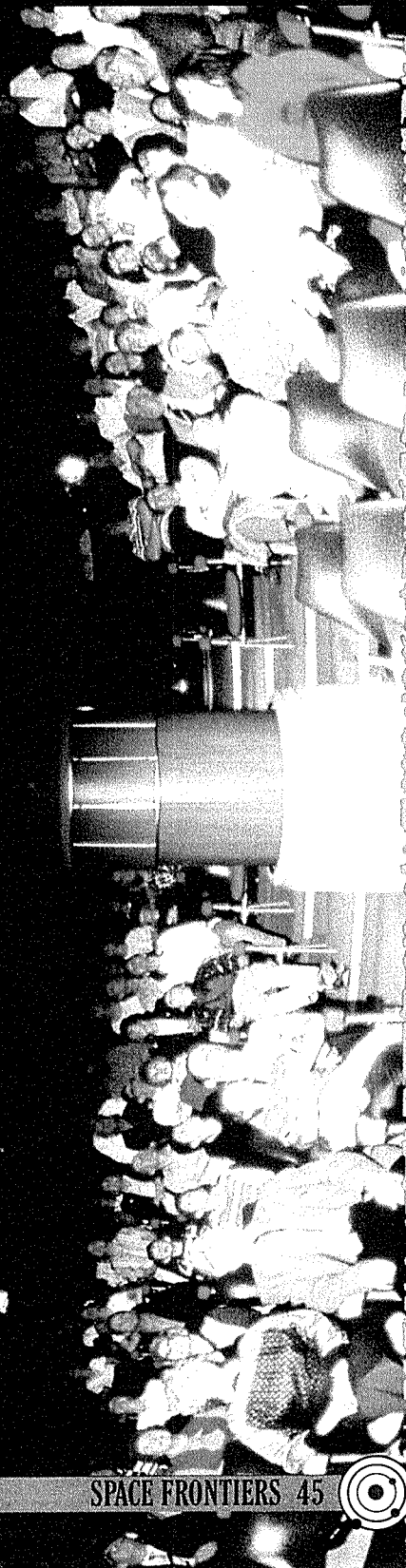


The night sky

A typical planetarium projector consists of two moveable globes fitted to either end of a cylinder that is supported by a metal framework. One globe projects stars visible from the northern hemisphere, while the other projects stars visible from the southern hemisphere.

Special effects thrill planetarium audiences with close-ups of exploding stars, alien landscapes and travelling spacecraft. The projector (above) is often part of the show.

David Parker/Science Photo Library



As many as 16 fixed projectors in each globe, illuminated by a central lamp, cast images of several thousand stars on to the dome. As the globe turns it simulates the movement of the constellations across the sky caused by the Earth's rotation.

The stars remain in the same position relative to one another. But the Sun, Moon and planets move against

HEAVEN IN A BOX

With the advent of powerful personal computers, maps of the stars and planets can now be viewed at home. A variety of night sky programmes are available for micros. To set up such a programme, the user simply enters the time, date, and location from which he or she wishes to view. The software then calculates the corresponding position in the sky of the stars, planets, Sun, and Moon and displays the results on the monitor screen.

the starry background. Because of this, separate projectors are needed for each of these objects. The variable projectors are located on the framework between the star globes. Like the globes, they are moved by motors and precision gear systems.

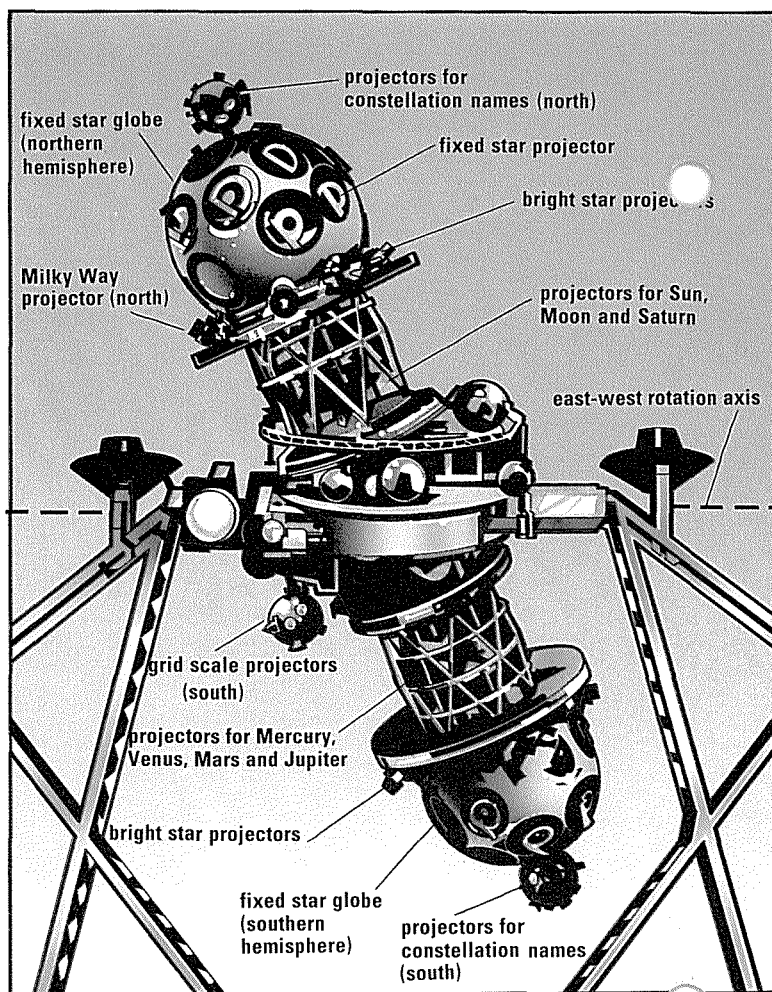


Time travel

From a central console, the projector is controlled to show any part of the sky at any time in the past, present, or

The Zeiss planetarium projector has 16 small projectors on either globe – each with its own optical system. Most projectors move about three axes to allow observation from any latitude on Earth, at any time of day and at any era in time.

Galaxies viewed from inside the stone circle at Stonehenge, UK. By turning a projector on its east-west axis, the sky can be seen from anywhere on Earth. At the North Pole stars appear to circle overhead without rising or setting. Stars over the southern hemisphere appear unfamiliar to inhabitants of the northern hemisphere and vice-versa.



presentation that both entertains and informs the audience.

Increasingly, television projection systems are replacing the earlier optical-mechanical projectors. These new, electronic projectors, linked to computers, take audiences on imaginary high-speed journeys through interstellar Space, showing the heavens from perspectives other than the Earth's surface; for example from the Moon, Mars or Venus.

Paul Desmond

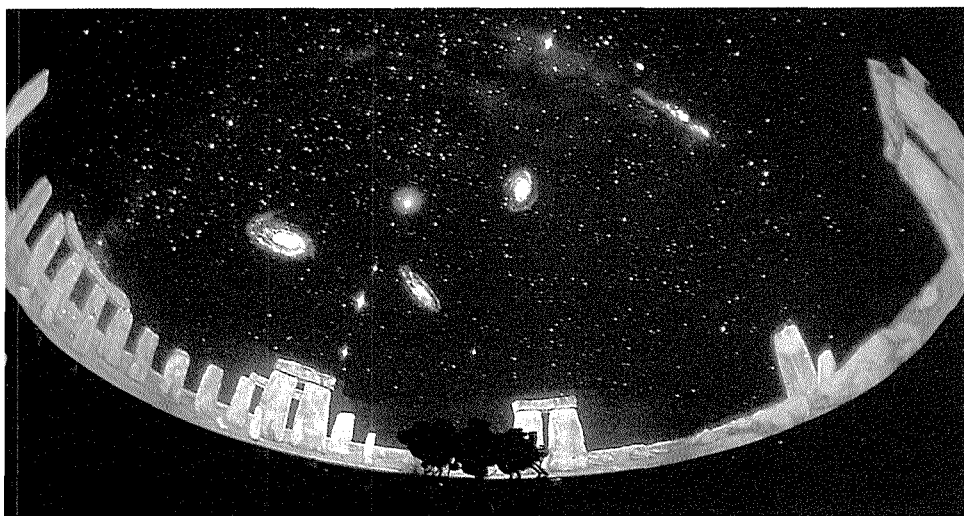
Just amazing!

SPEED READING

THE EARTH MOVES AROUND THE SUN AT OVER 1,600 KM PER MINUTE. WHILE READING THIS PAGE YOU WILL HAVE TRAVELLED SEVERAL HUNDRED KILOMETRES THROUGH SPACE.



Paul Raymond



London Planetarium

future. It can track the movement of stars throughout a single night, the movement of planets throughout a whole year, or the changing appearance of the sky over a much longer period of time. For example, the Earth's axis does not remain pointing in the same direction in Space. It wobbles like a spinning top. One wobble takes 25,800 years to complete (the period of precession). This enormous time-span can be compressed into just a few minutes in the planetarium.

One of the largest projector types is the Zeiss instrument at the London Planetarium. Measuring 4 metres in length, it weighs over 2,000 kg and

contains some 29,000 individual parts. The Sun, Moon, planets and brightest stars in the sky are represented by individual projectors. Further projectors display the Milky Way, the names of the constellations, and a grid for measuring star positions in the sky.



Multi-media show

Many planetariums create special effects to compliment their sky shows. These include pre-recorded voice commentary and music, and superimposed still images from slide and motion picture projectors. The result is an impressive multi-media



CURVY SPACE-TIME



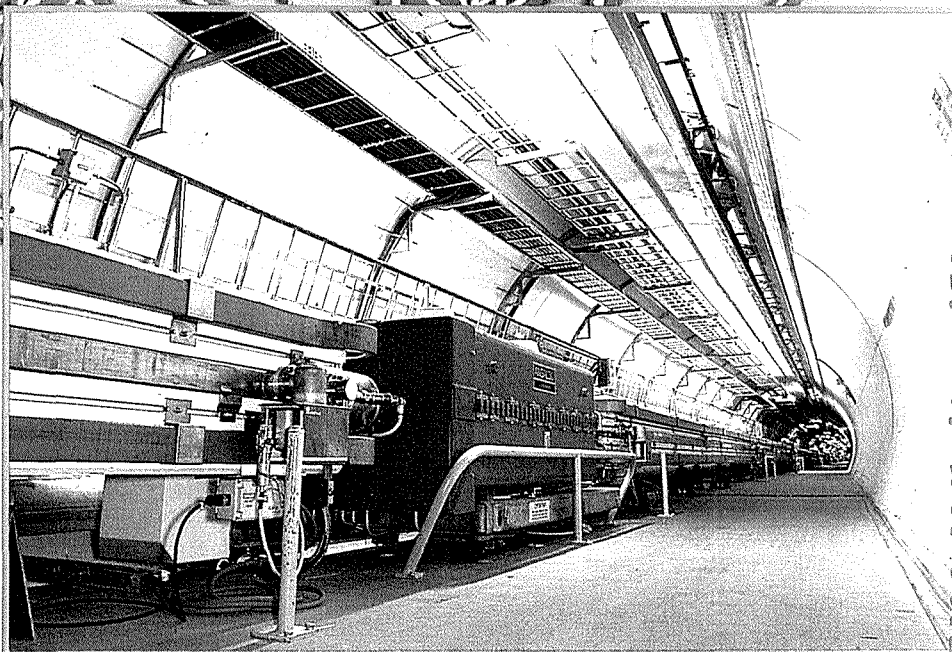
GALAXY CLUSTERS



MASSIVE PARTICLES

HIDDEN DIMENSIONS

The curved tracks of subatomic particles may reveal clues to hidden dimensions. But an accelerator (below) stretching to the nearest star would be needed to push particles into another dimension.



Patrice Loiez/CERN/Science Photo Library

THE EVERYDAY WORLD WE live in has three dimensions. It has height, width and depth. But it is quite possible to imagine what it must be like to live in a world with a different number of dimensions – and it can be quite useful too.

In a one-dimensional world, you would be at a point that was confined to a line. You could move up and down it, but you would have no direct knowledge of anything outside that line. To define your position in this one-dimensional world all you would need is one number saying how far along the line you were from a reference point. Once you had picked a reference point on the line you could define where you were by saying that you were 5 cm or 10 cm from that point. If you were 5 cm or 10 cm down the line, on the other side of the reference point (which you would mark as 0, as it was 0 cm from itself), your position would be defined as –5 cm or –10 cm from the reference point.



In two dimensions

However, a one-dimensional being may infer that a second dimension exists, if he was living on a loop, for example. If he headed off in one direction and some time later ended up back where he started, this could only be explained by a hitherto unobserved dimension.

If you lived in a two-dimensional world, you would live in a world with

area but without thickness, like the people in a picture. Both paper cutouts lying flat on a table top and shadows on a wall inhabit a two-dimensional world.



Defining your position

To define where you were in this world, you would need two numbers. You could say that you were 4.62 cm east and 3.89 cm north of a particular reference point. In this world you could wander about, but you would not be able to tie knots or jump in the air as these things would require a third dimension.

A being from this two-dimensional world – a 'Flatlander' – would not be able to see a third dimension but might be able to infer one if he lived on the surface of a sphere, for example. If four intrepid Flatlanders set off in four different directions at the same speed, they would all meet at a point on the opposite side of the sphere. This could only be explained

by an unobserved third dimension.

In our world, a sailor, for example, can define his position by just two numbers – a latitude and a longitude – that fixes his position only because he must be on the surface of the Earth. However, it could be said that we really live in a four-dimensional world. For an airline pilot to define precisely where he is, he has to give the time and date as well as his latitude and longitude. The time – and date, which is only a larger measure of time, the number of years, months and days since the birth of Christ – can be considered as a fourth dimension.



Bending light beams

Physicist Albert Einstein discovered that if you treat time as a fourth dimension, gravity will be a curve in four-dimensional space-time. Light was once thought not to be affected by a gravitational field, but in 1919 it was discovered that light from distant stars is bent around the curve in

David Parker/Science Photo Library



space-time caused by the gravitational pull of the Sun – showing Einstein's theory to be correct.

Soon after, Soviet physicist Theodor Kaluza showed that if there were five dimensions, then gravity and electromagnetism would be manifestations of a single force. Since then, mathematicians have worked out that all the known forces – gravity, electromagnetism and the so-called strong and weak forces that operate inside the atomic nucleus – are in fact a single force. The key to this, however, is that there must be 11 dimensions.

The problem then is to explain why

we are aware of only four of them. Scientists have suggested that there were perhaps 11 dimensions when the Universe was born. But an inconceivably short time after the 'Big Bang', when matter, energy and space-time itself were created, seven of the dimensions 'curled up' and they all but disappeared as the Universe expanded and cooled. But they are still present, forming an unperceived universe 'next door' to our own.

Into new dimensions

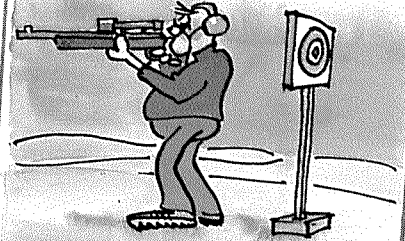
We can see dimensions 'curl up' in the real world. If a ball is viewed close up, you can see its ball-like structure – it has three dimensions. But if it is viewed from a great distance, it looks like a point which has no dimensions.

A subatomic particle could, in principle, enter the extra dimensions, seeming to vanish from our world for an instant, and then quickly return. But fantastically high energies would be needed to push a particle into an-

Just amazing!

GUN HO

IF YOU COULD SHOOT A BULLET AT 64,000 KM/H AT THE NORTH POLE, ABOUT HALF AN HOUR LATER IT WOULD HIT YOU IN THE BACK OF THE HEAD.



Paul Raymond

other dimension. With present technology, you would need a particle accelerator several light years across – stretching, say, from here to the nearest star.

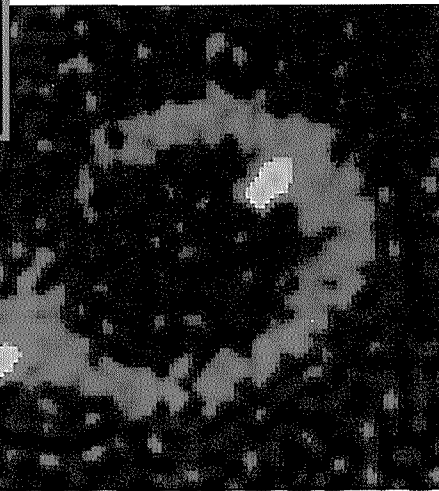
The Big Bang

But back at the time of the Big Bang, when these energies would have been available and switching between the extra dimensions would have been easy, particles 1.019 times the mass of a proton – which is still only around 1/100,000th of a gram – would have been created.

Some of these so-called 'massive' particles might still exist today and scientists throughout the world are looking for them. The discovery of such particles would reveal the existence of the hidden dimensions.

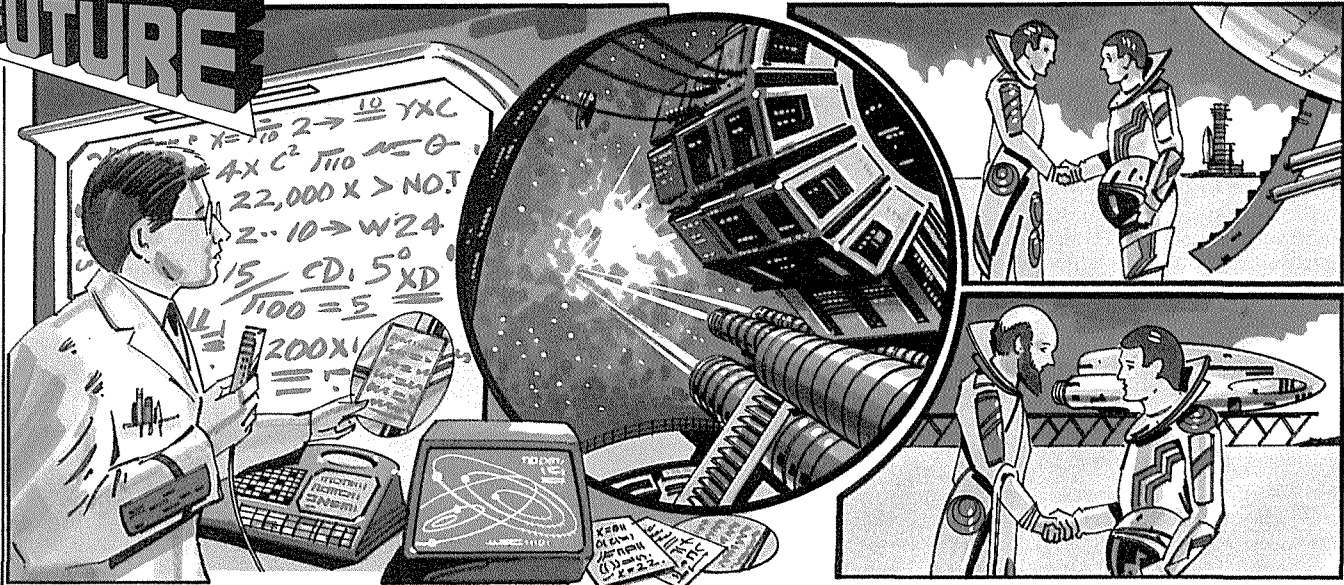
NRAO/AUI/Science Photo Library

The huge gravitational pull of a galaxy deforms four-dimensional space-time. This force creates a massive 'gravitational lens' in space that spreads light or radio waves from a single source into an arc or a full 'Einstein ring' (right).



INTO THE FUTURE

THE KEY TO TIME TRAVEL



▲ Although it is impossible to travel back in time, scientists have calculated the strange, time-warping effects of travelling at speeds close to that of light.

▲ If a spaceship were to travel at 99.9 per cent of the speed of light, time for the astronauts on board would run over 20 times slower than time on Earth.

▲ If they returned after what was, to them, a one-year flight, an astronaut would find that his twin brother had aged by more than 20 years.

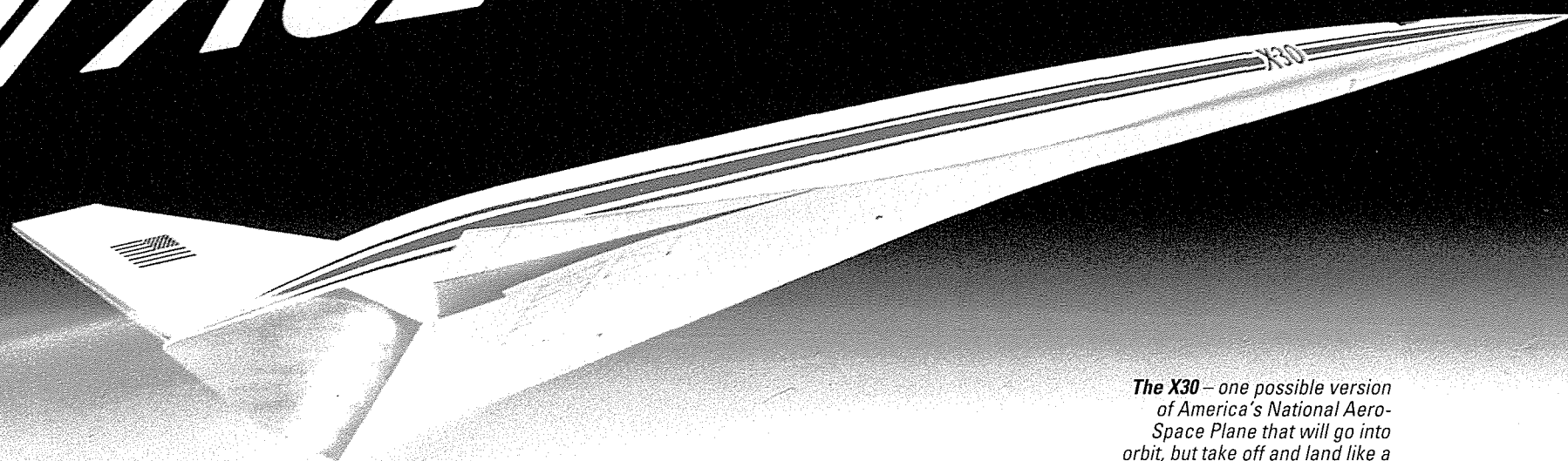
Joe Lawrence

SCRAMJETS

HOT SPOTS

MOTHERSHIPS

SPACEPLANES



The X30 – one possible version of America's National Aero-Space Plane that will go into orbit, but take off and land like a conventional aircraft.

NEXT CENTURY, SPACECRAFT will take off from a runway like ordinary aircraft, accelerate to a speed of about 29,000 km/h and then climb into the rarified atmosphere of Space over 150 kilometres above the surface of the Earth.

The idea for a Space plane goes back over 30 years, but the race into Space led to massive rockets being used to power launch vehicles instead. At that time, experimental Space planes that were carried to the edge of the atmosphere by massive

bombers were abandoned. Both the United States and Russia have developed Space shuttles that can land like a plane. So far, though, no one has built a vehicle that can fly up to Earth orbit without the help of large rocket boosters, but there are several Space plane designs now in an advanced stage of development.

America's plans

Plans for America's National Aero-Space Plane (NASP) show a sleek, wedge-shaped craft 50 metres

long – 9 metres longer than the Space Shuttle. Four different types of engine slung under the wings and fuselage will propel the Space plane to its final speed of 25 times the speed of sound, or Mach 25.

To take off and accelerate up to Mach 2 – about 2,250 km/h – the NASP will use turbojet engines similar to those aboard large passenger airliners. The NASP turbojets have a spinning fan at the front to suck air into a combustion chamber and compress it. Once inside the combustion chamber, the air is mixed with hydro-

gen fuel and ignited. As the hot exhaust gas escapes from the back of the turbojet, it produces a forward thrust and turns a second set of blades that drive the front turbine.

Ramjets take over

Above Mach 2, the oncoming air will be moving so fast that it will compress itself, making the turbojet's spinning blades more of a hindrance than a help. At this stage, the turbojets are shut down and a second set of engines, known as ramjets, allowed to take over.

DOD/Science Photo Library



Ramjets are like turbojets without turbines. As the Space plane moves quickly forward, air rushes into the front opening of the ramjet and 'rams' itself, at high pressure, into the combustion chamber. The increased rate at which air is gulped in by the fast-moving plane will offset the fact that oxygen is more rarefied at these higher altitudes.

Scramjets

The NASP's ramjets will continue working up to a speed of between Mach 6 and Mach 8 (between 6,750 and 9,000 km/h). Above Mach 8, air molecules can break apart as they enter the engine, using up energy that could otherwise be used to power the Space plane. So, a third set of engines, called scramjets – or supersonic combustion ramjets – will kick in. These channel the air through narrow internal ducts that prevent the molecules breaking apart.

Scramjets will take the Space plane to Mach 20 – and to the edge of Space. At that point the air runs out,

NASA



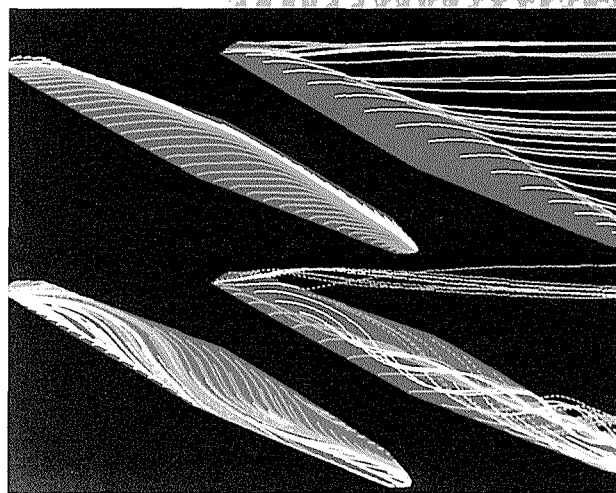
A computer simulation of the air flow over the fuselage of a proposed design for a Space plane. This work is vital as a Space plane must be able to cope with air at the density and pressure of the atmosphere at ground level as well as the greatly reduced pressures that it will encounter on its way into Space.

composites. These materials can withstand temperatures up to about 1,650°C.

Certain parts of the Space plane, however, will get even hotter than this. Temperatures at leading edges,

SCREEN TESTS

The extensive use of computer simulation means that every modification of a design does not have to be built into a model and tested in a wind tunnel. Computer programs using simulations of air flows can be used to weed out impractical designs quickly, leaving only the most promising to go forward to expensive and time consuming wind tunnel tests. Here the airflow over a



NASA

wing is modelled at different angles of attack. Once the wing configuration looks right on screen, it will be incorporated into the complete design. And when all the elements satisfy the simulation, the model builders get to work – to check that it is accurate

Philippe Plailly/Science Photo Library



so regular liquid hydrogen and liquid oxygen fuelled rocket engines take over, pushing the Space plane up to Mach 25 and out into orbit.

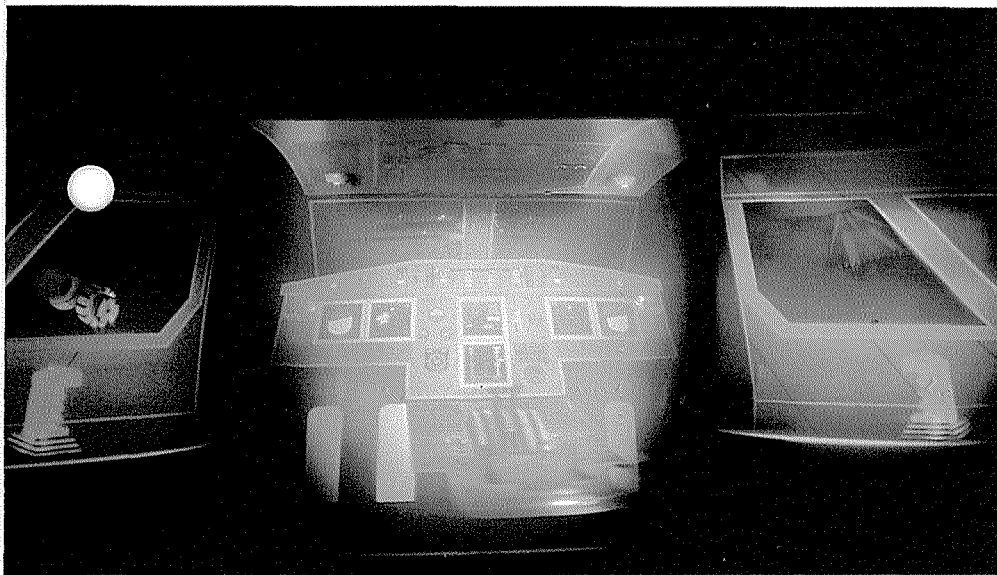
Cooling systems

In the past, spacecraft have been protected, during their high-speed passage through the atmosphere, either by a conventional heat shield or – in the case of the Shuttle – a layer of thermal tiles. But the Space plane will need a more advanced method of staying cool. This is because – even though it is travelling a good deal slower than conventional rocket-mounted spacecraft – it will be subjected to frictional heating for much longer periods.

Flying most of the way into Space

A model of Hermes, the European Space Shuttle, and its Ariane-5 rocket are put through wind tunnel tests. Magnesium powder shows air flow and blue-green laser light detects turbulence.

along a gentle, 15 to 20 degree incline, the NASP will pass through hundreds of kilometres of air at speeds of up to Mach 20. To protect the craft during these long, hot ascents, most of its external surfaces will be covered with light, heat-resistant titanium aluminide and carbon



Flight deck simulations of Hermes are made as holograms. Through the left-hand window, there is a Space station Hermes is about to dock with. Through the right, there is runway on Earth that Hermes is about to land on.

weeks to prepare for launch. This is because the orbiter has to be fitted to a large external fuel tank and two solid rocket boosters. Then the whole assembly has to be tediously rolled out to the launch pad on the back of a giant crawler transporter.



Ready for take-off

By contrast, a Space plane like the NASP would sit on the runway like a conventional plane and could be fueled up and made ready for take-off in a very short time. As a result, it could respond to life-threatening emergencies in Earth orbit, such as major equipment failure aboard a Space station or rescuing a dangerously ill member of the crew.

Within a few hours, the NASP could be launched on a rescue mission carrying spare parts, air and fuel

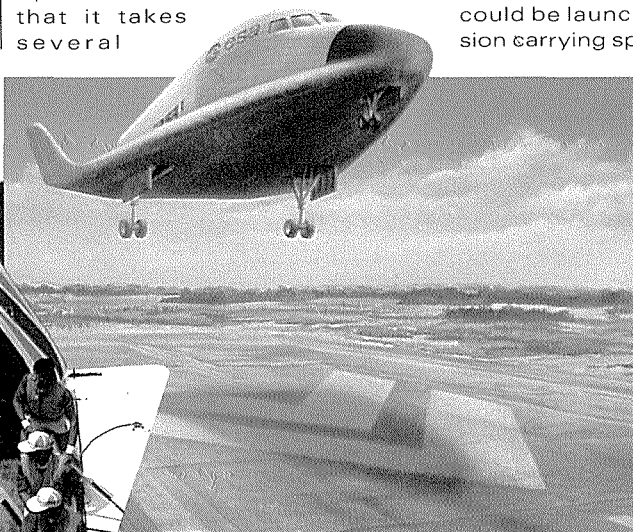
such as the nose and front of the wings, may climb to between 2,200 and 2,750°C.

Heating the fuel

To protect these areas, a special copper alloy will be used. Beneath the hot spots, the liquid hydrogen fuel will circulate through pipes one five-thousandth of a millimetre wide. The liquid hydrogen fuel is stored at -253°C for

on the way saves engine power and will add as much as 10 per cent to the plane's speed.

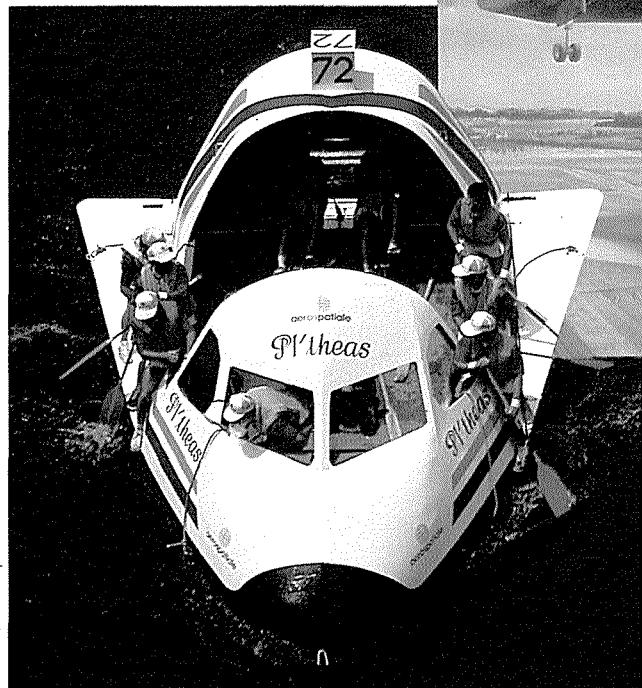
One of the problems with today's Space Shuttle is that it takes several



Hermes – the proposed European Space Shuttle – glides into land on a runway like the American Shuttle.

Hermes' crew of three will divide their time between the cockpit, a living area where they will work, and a resource module that will hold cargo and experiments and act as an air-lock for EVAs.

Ducros/Jerrican

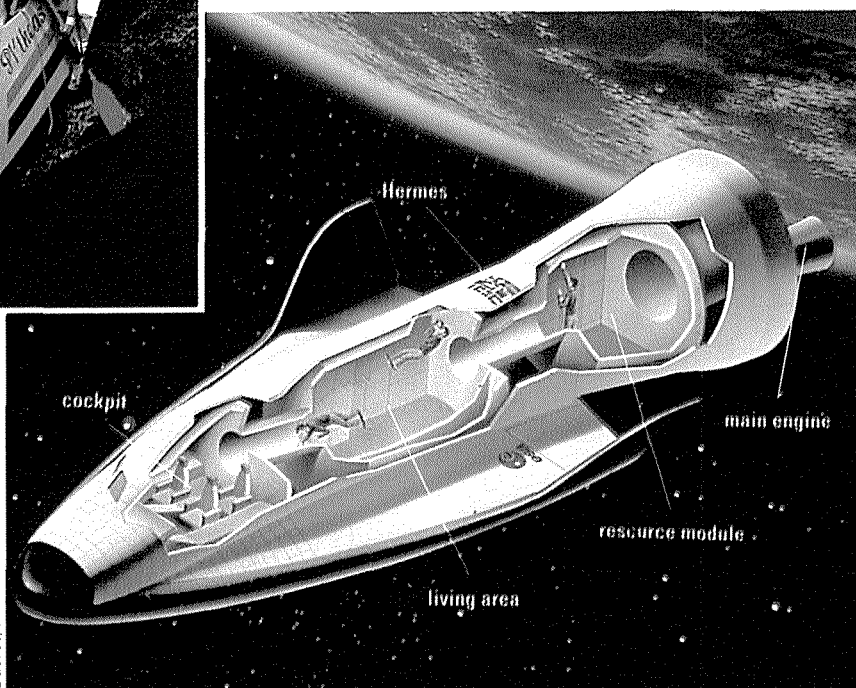


Gamma/Frank Spooner Pictures

Accidents can happen and every eventuality has to be planned for by Space plane designers. Hermes is tested to see if it can float, just in case its landing is aborted and it has to come down in the sea.

safety reasons. But as it passes under the hot spots, it will pick up the heat from the copper alloy, turning the liquid hydrogen into a 800°C gas ready to be pumped into the engine combustion chambers. The heat picked up

Ducros/Jerrican



Sanger – Germany's proposed Space plane – will use a large aeroplane as a 'mother ship' to carry the Space craft itself up to the edge of the Earth's atmosphere from where it will be launched into orbit.

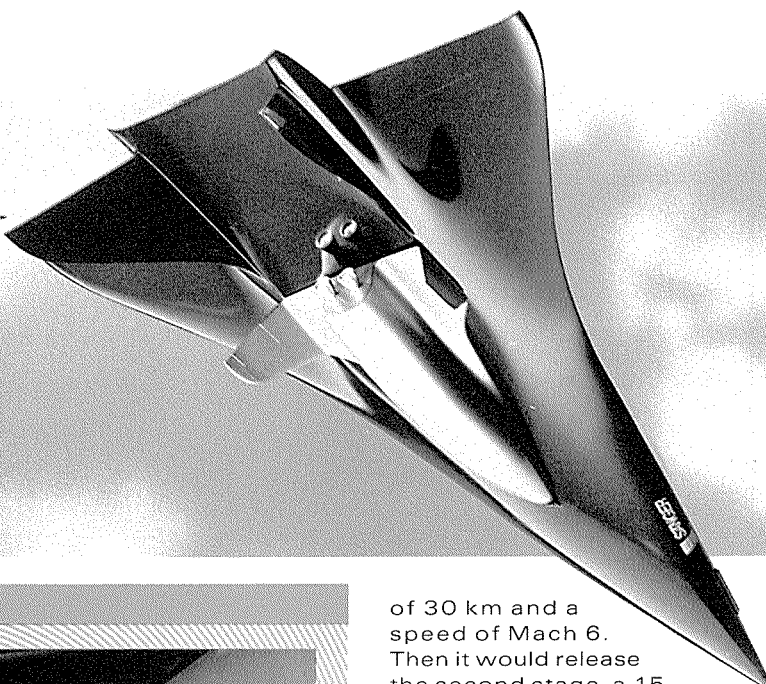
or emergency medical gear, or even bringing a sick astronaut back to Earth for treatment.



Two-stage craft

Other countries are looking at the possibility of building Space planes. Germany has been planning a two-stage, re-usable craft called Sanger. The first stage of Sanger

Gamma/Frank Spooner Pictures



PEGASUS



Gamma/Frank Spooner Pictures

Early in 1990, a new type of launch vehicle, called Pegasus, made its maiden voyage into Space. It was carried to a height of about 12,000 metres slung underneath a B-52 bomber before completing its journey into orbit under its own rocket power.

The 18-tonne, 15-metre-long Pegasus looks like a missile with a pair of stubby wings. Packed into its fuselage

are three stages, each with its own solid-fuel motor. These are capable of delivering small satellites, weighing up to 450 kilograms into a low orbital trajectory around the Earth. The use of a carrier plane should help Pegasus to halve the cost of a conventional launch as well as eliminate the risk involved in launching rockets at ground level near populated areas.

of 30 km and a speed of Mach 6. Then it would release the second stage, a 15-metre long, winged craft equipped with rocket engines that would blast it into orbit, while the mothership flew back to Earth. When its mission was completed, Sanger would glide back to Earth like the Space Shuttle.

France, meanwhile, is spearheading the development of the European Space Agency's three-man mini-shuttle, called Hermes. Though not a true Space plane in that it will be launched on top of an Ariane 5 booster rocket, Hermes too will glide back to Earth like an aircraft.



Four-in-one engines

Britain also began studies of a horizontal take-off and landing Space plane, known as HOTOL, which used a revolutionary design of engine that changed configuration from turbojet through ram- and scramjet to rocket engine as speed increased. However, lack of government support led to the project being cancelled by the British government, though funding is being sought from other sources.

Japan and Russia are the other

McDonnell Douglas/DOD

Just amazing!

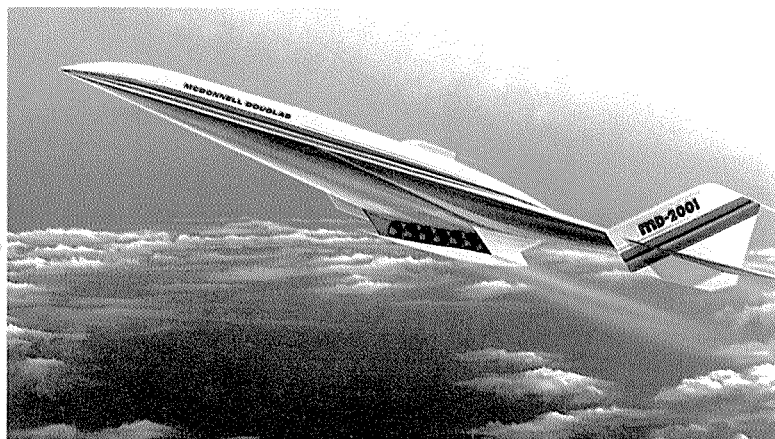
THE ORIENT EXPRESS

THE US NATIONAL AERO-SPACE PLANE HAS BEEN NICKNAMED THE 'ORIENT EXPRESS' BECAUSE IT WILL SOMEDAY WHISK PASSENGERS BETWEEN NEW YORK AND TOKYO IN TWO HOURS!



Paul Raymond

The MD-2001 – McDonnell Douglas's version of America's National Aero-Space Plane – will carry passengers from Washington to Beijing in two and a half hours. But it will also have military uses and is being developed in partnership with the US Navy and Air Force as well as NASA.



would be a 400-tonne, 52-metre-long, piloted mothership with a wingspan of 25 metres.

Powered by air-breathing jets that would use oxygen from the air to burn the fuel, it would fly to a height

principal nations involved in Space plane design. By early next century, it seems that the NASP and a few international rivals will have begun a new chapter in the history of Space exploration.



ASTROBOTS AND BOLTS

SATELLITE REPAIR



ANCHORING

GRIPPING



The remote manipulator arm, the giant Canadian-built handling tool, on board the Shuttle. Here it is being used to deploy the Hubble telescope.

CARRYING OUT REPAIRS and other tasks in Space calls for a wide variety of tools, from ordinary spanners to multi-million-dollar devices specially made for a particular mission.

Some of the most sophisticated tools have been developed to enable shuttle astronauts to capture and recover crippled orbiting satellites. In April 1984, the shuttle Challenger was launched with an assortment of

special equipment aboard to help repair the damaged Solar Max satellite. After the shuttle had moved to within 60 metres of its target, Astronaut George Nelson used a Manned Manoeuvring Unit (MMU) to propel himself over the faulty spacecraft.

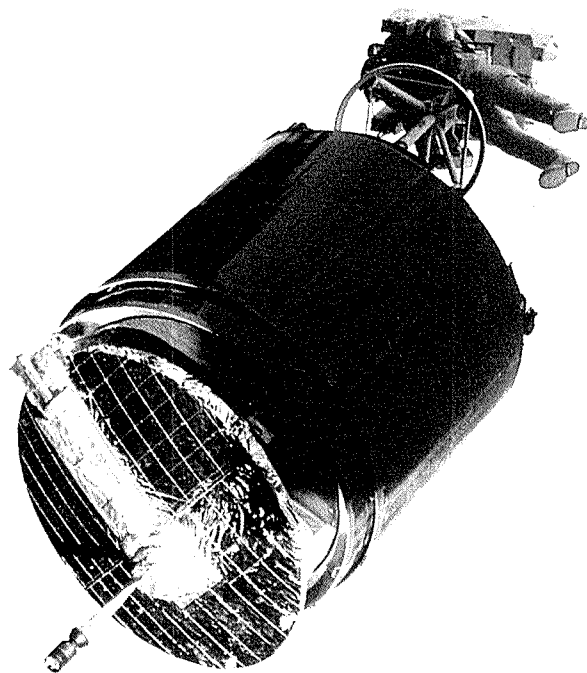
Locking on

Attached to the front of the MMU was a device called a T-Pad. With this, it was hoped that Nelson could lock on

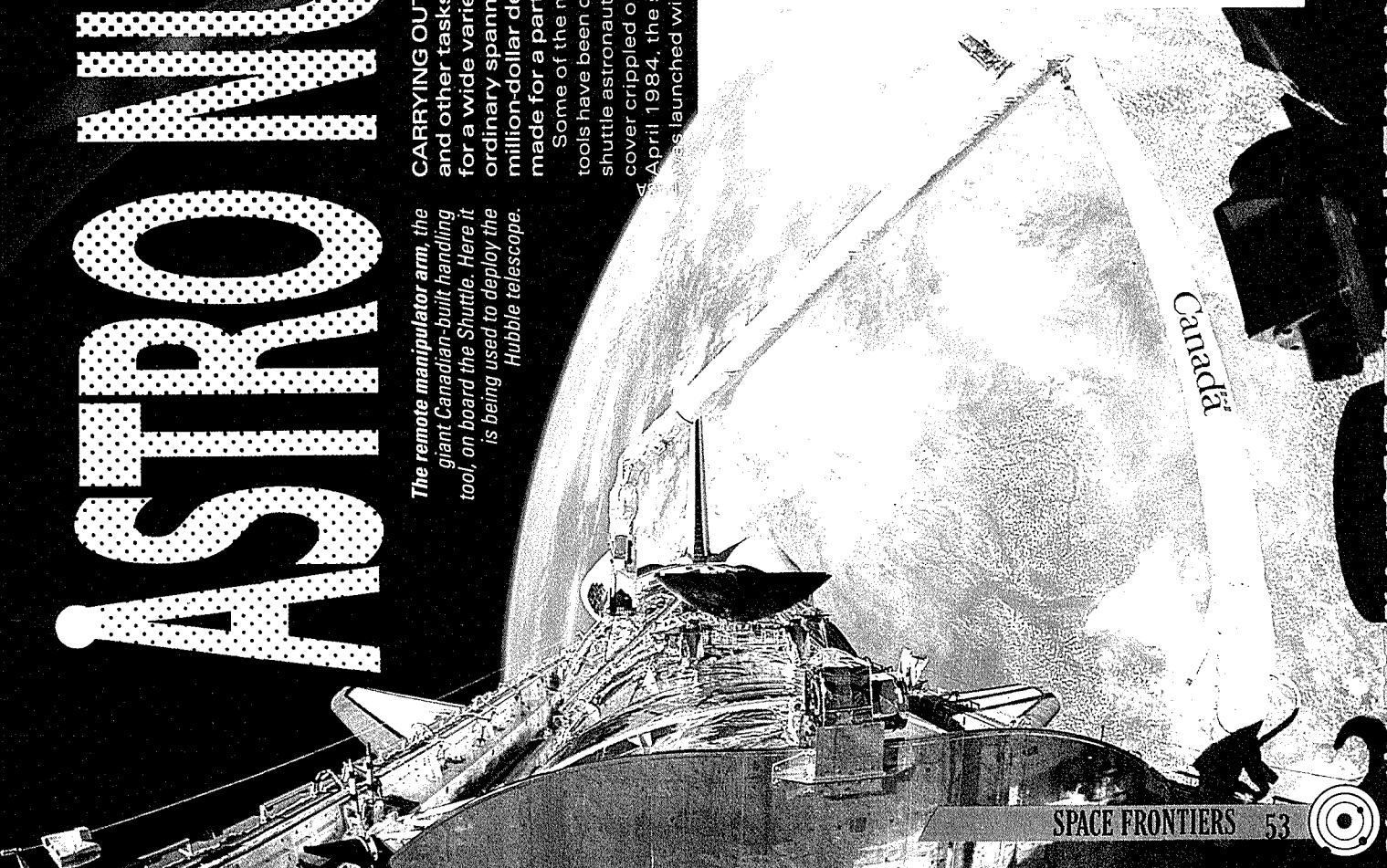
to a metal pin projecting from the side of the satellite and then use his MMU's thrusters to nudge Solar Max into the shuttle's payload bay.

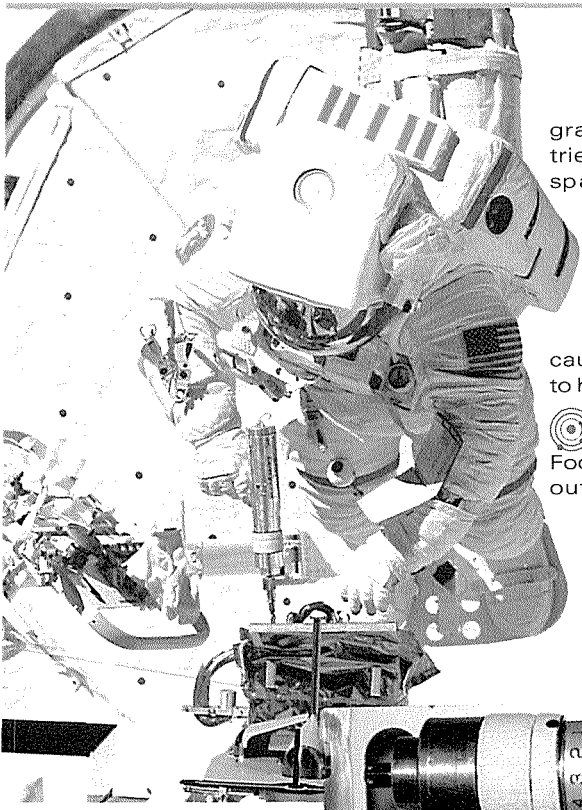
Although, in the event, Nelson failed to attach the T-pad, another tool – the shuttle's robot arm – succeeded in catching hold of the satellite. With Solar Max safely in the payload bay, astronauts removed fasteners on the satellite's main electronics box using a special, battery-operated power tool,

Astronaut Dale Gardner captures a broken *Westar VI* communications satellite with a specially designed tool, the 'apogee kick motor capture device'. This jams *Westar's* spent engine, stabilizing the spinning satellite. Once it is under control the astronaut can manoeuvre it back into the Space Shuttle's cargo bay.



NASA





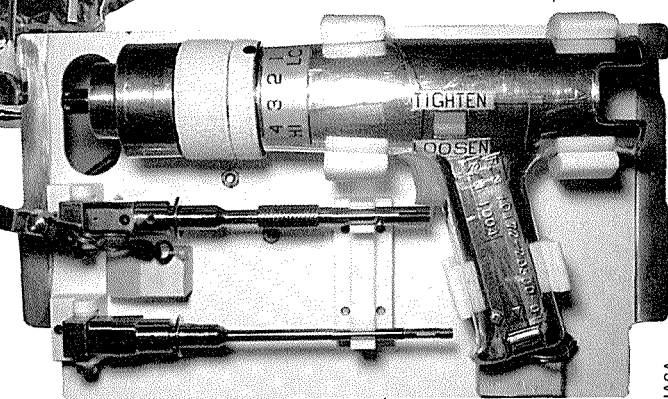
NASA/Science Photo Library
Bruce McCandless using a special screwdriver (right) in the Shuttle's cargo bay. His feet are anchored by the mobile foot restraint on the manipulator arm.

gravity. For example, if an astronaut tries to undo a nut using an ordinary spanner, he would rotate his entire body in the opposite direction.

There are two possible solutions. The first is to provide a means for astronauts to anchor themselves firmly before starting a job. The MMU is ideal for this because its thrusters fire automatically to hold it steady in position.

Anti-torque tools

Foot restraints, on both the inside and outside of spacecraft, can also hold an astronaut still while working in orbit. Another solution is to design new tools specifically for use in zero gravity. Anti-torque tools, for example, would counter any twisting force exerted by the astronaut with an equal and



similar to a hand drill. Having replaced the broken module, they resealed the unit, and then hoisted the satellite back into orbit with the robot arm.

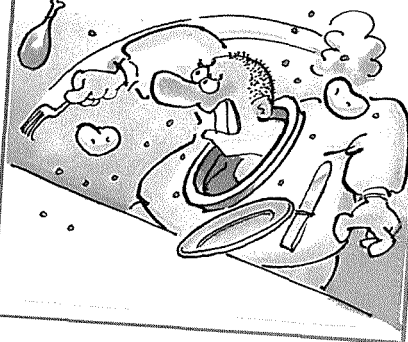
One of the biggest problems with using tools in Space is the lack of

opposite force. So-called 'reaction-less' tools balance out any pushes or pulls. In each case, the astronaut could use the tools without being made to spin or drift away. Studies have already been done on reaction-less, mechanical hammers and saws,

Just amazing!

EATIQUETTE

EVERYDAY TOOLS THAT WE TAKE FOR GRANTED ON EARTH – LIKE CUTLERY – HAVE NO PLACE IN SPACE. A SPOON, FOR EXAMPLE, IS USELESS IN ZERO-GRAVITY.



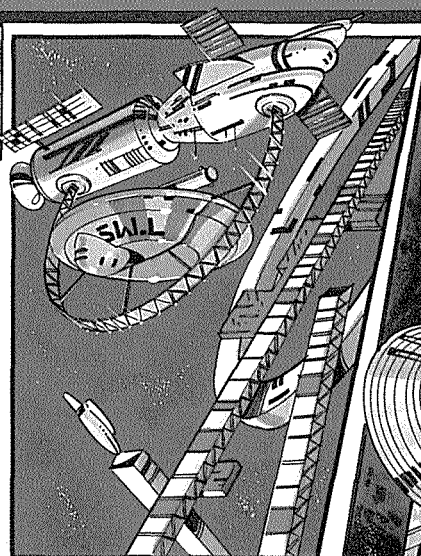
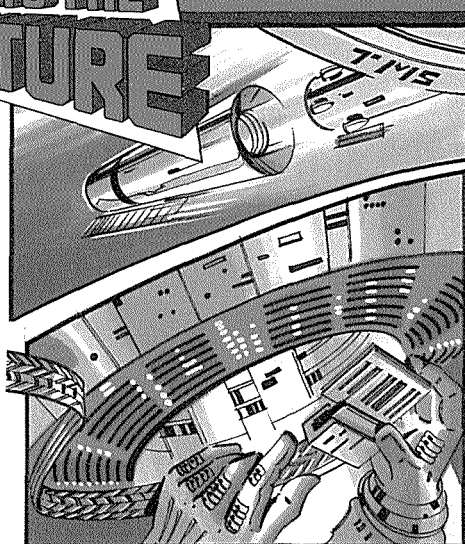
Paul Raymond

and a multi-purpose power tool that can act as a reversible drill. Other useful items in an orbital repair kit include a glove with rubbery pins on the surface for better gripping, a gluing tool and devices for cleaning up debris at the end of a job. In all cases, tools must be tethered to the astronaut's suit to prevent them from simply floating away into Space.

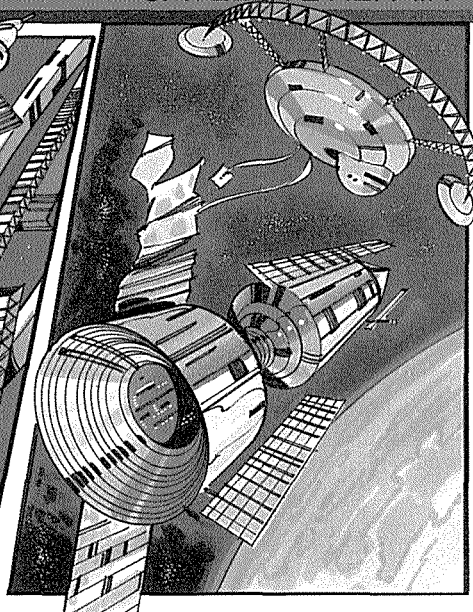
Maintenance

Fixing a satellite in orbit may be expensive, but it is much cheaper than building and launching a new one. For this reason, satellites in the future will be designed for easy maintenance and repair. Astronauts will use a range of standard tools to unplug faulty modules and replace them with new ones brought up from Earth.

INTO THE FUTURE



SATELLITE REPAIR



▲ As fixing satellites or other spacecraft in orbit is much cheaper than building and launching new ones, they will be designed for easy maintenance and repair.

▲ Under remote control, a robot Space tug called a teleoperator manoeuvring system (TMS) will move a broken-down satellite, for example, to a Space station.

▲ At the Space station astronauts will unplug faulty modules and replace them with new ones from Earth. The TMS then returns the satellite to its original orbit.

Q NUCLEAR CORE

Q SUN SPOTS

Q CORONA

THE MIGHTY SUN

IF THE NUCLEAR FURNACE at the heart of the Sun were to go out, it would be 10 million years before the effects were felt on Earth. That is how long it takes for heat and light radiation to battle its way up through the dense interior of the Sun to its surface.

Once at the surface though, it takes only eight minutes for the Sun's heat and light waves to travel to the Earth.

The heart of the Sun is very hot and very dense. The temperature is some 15 million degrees Celsius and over 160 tonnes of matter are jammed into every cubic metre. This matter consists mostly of hydrogen, but not hydrogen as it exists on Earth.

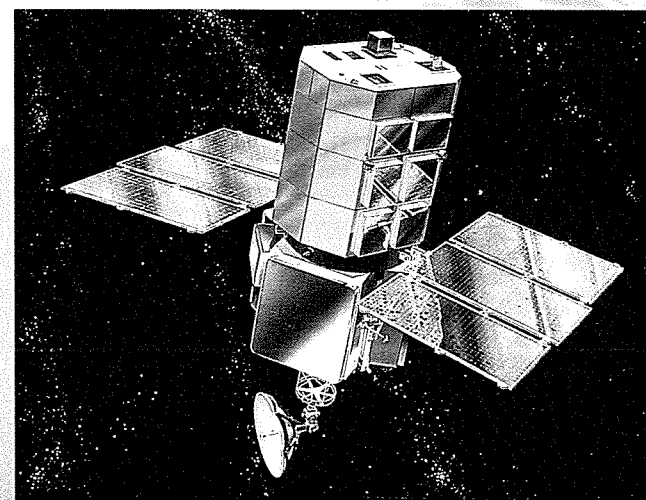
Crushed atoms

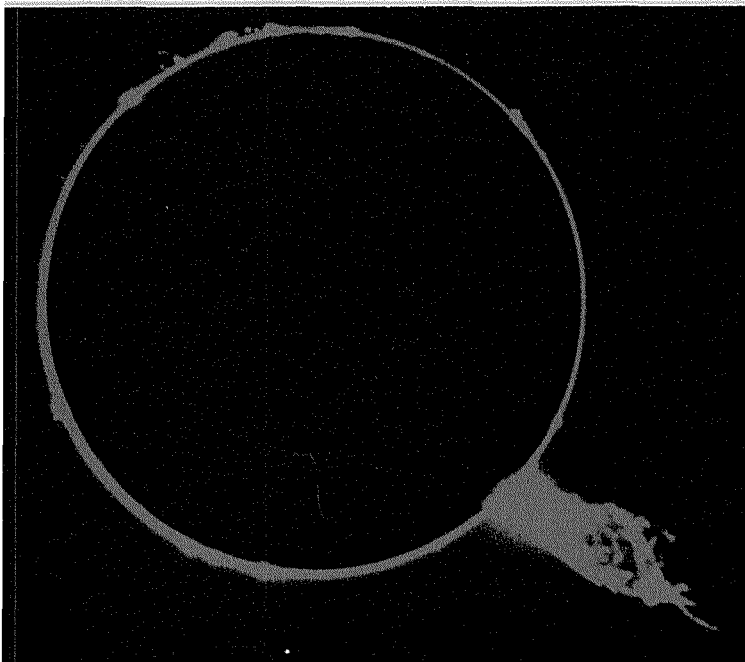
Normally, matter exists in the form of atoms, each of which has a tiny core, or nucleus, around which electrons

orbit. But at the pressures and temperatures prevailing in the Sun, atoms are crushed together until their nuclei and electrons move independently.

The hydrogen nuclei constantly collide and fuse, eventually forming

***The Sun** is the force behind the solar system. Satellite Solar Max (right) was launched by the Space Shuttle to study its curious 22-year cycle of activity.*

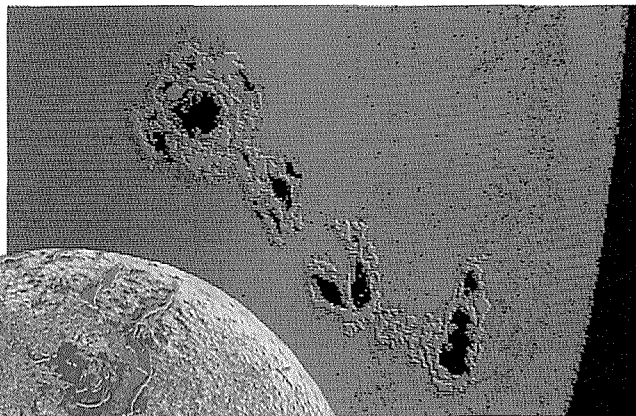




Huge prominences of glowing red hydrogen shoot out into Space from the fiery surface of the Sun. These can only be seen during a solar eclipse when the main body of the Sun is obscured by the Moon.

and forth. That is why it takes so long to emerge. About four-fifths of the way out, the process of convection takes over. Heat is carried outwards by hot gas rising to the surface.

At a temperature of 6,000°C, the surface of the Sun is a brilliant sight (though you should never look at it directly). But when it is examined minutely with astronomer's instruments, it is mottled, or patchy, with ever-changing bright areas of hot,



False colour image showing sunspots as green dots. Active regions are red. The green lines are filaments – near the Sun's edge they would show as prominences. Sunspots (above) just before the height of the 11-year cycle.

Nigel W Scott/Science Photo Library

more massive nuclei of helium. This is essentially the same process as the one that powers the hydrogen bomb.

When the four hydrogen nuclei get together to form helium, they lose a tiny bit of their mass, which is given off as energy. So the Sun is constantly

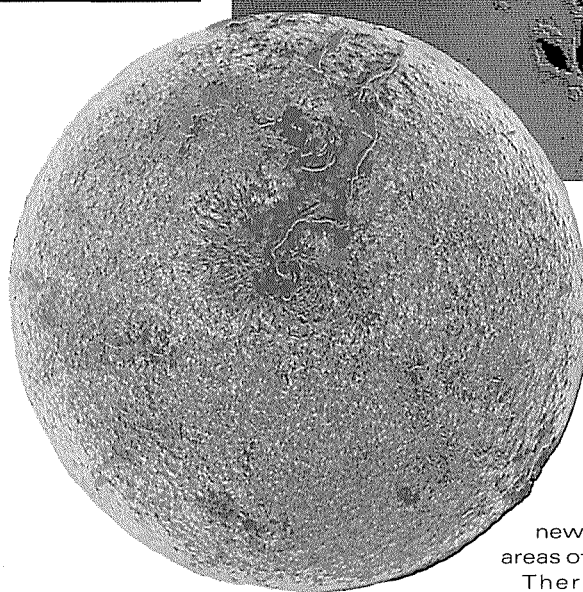
LOOKING AT THE SUN

Using smoked glass or dark glasses is *not* a safe way to look at the Sun, with or without binoculars or a telescope. The safe way is to project an image of the Sun on to a piece of white card. Mount the card behind the telescope or one of the eyepieces of a pair of binoculars as shown.

Another piece of card around the barrel of the instrument will shade the card on which the image is projected. If you do not have binoculars or a telescope, a small hole in the upper card will form a 'pinhole image' of the Sun.

The image produced is of low quality, but it will show clouds passing over the Sun, and even large sunspots if any are present at the time. Solar prominences and the corona cannot be seen except with specialized equipment or during total eclipses of the Sun, which are very rare.

Science Photo Library



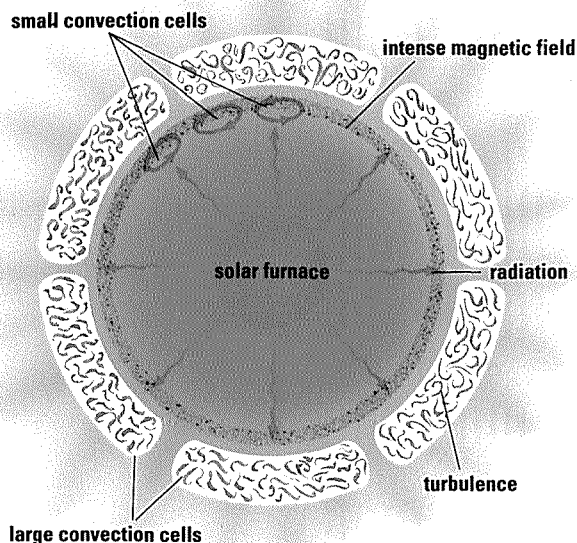
losing mass – in fact, around four million tonnes of the Sun's mass vanishes every second.

The energy generated radiates in the form of light, X-rays and radio waves, bouncing off the densely packed nuclei and zig-zagging back

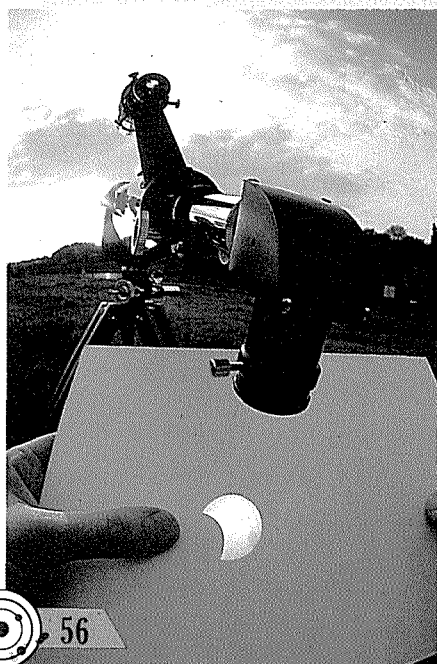
newly risen gas among darker areas of cooler, sinking gas.

There are usually large sunspots to be seen that appear slightly dark compared with their dazzling surroundings. Sunspots appear where magnetic fields trapped inside the Sun burst through the surface. These slow down the convection of gases, allowing patches to cool.

In the dense core of the Sun, energy radiates outwards as light, X-rays and radio waves. In the outer fifth though, the plasma is less compact, allowing huge zones of convection to form where cells of swirling hydrogen carry the energy to the surface.



Mark Franklin



David Parker/Science Photo Library

Magnetic fields outside the surface are often traced out by great arching streams of glowing red hydrogen. Called prominences, they dwarf the Earth, sometimes extending to half the width of the Sun.

Extending far beyond the Sun is a very thin but extremely hot solar 'atmosphere'. This is called the corona and has a temperature of two million degrees Celsius. Particles from the corona escape, causing the solar wind. Some of these are captured by the Earth's magnetic field. As they spiral towards the Earth's magnetic poles, they hit the atmosphere causing the northern and southern lights.

☉ Solar cycles

Solar activity goes through a regular cycle. The number of sunspots grows over a period of about four years, then decreases for about seven years. When the number of spots is at a maximum there are more prominences and flares -

A thick ring corresponds to a wet year when the tree grew more. Eleven year cycles can be found in these rings.

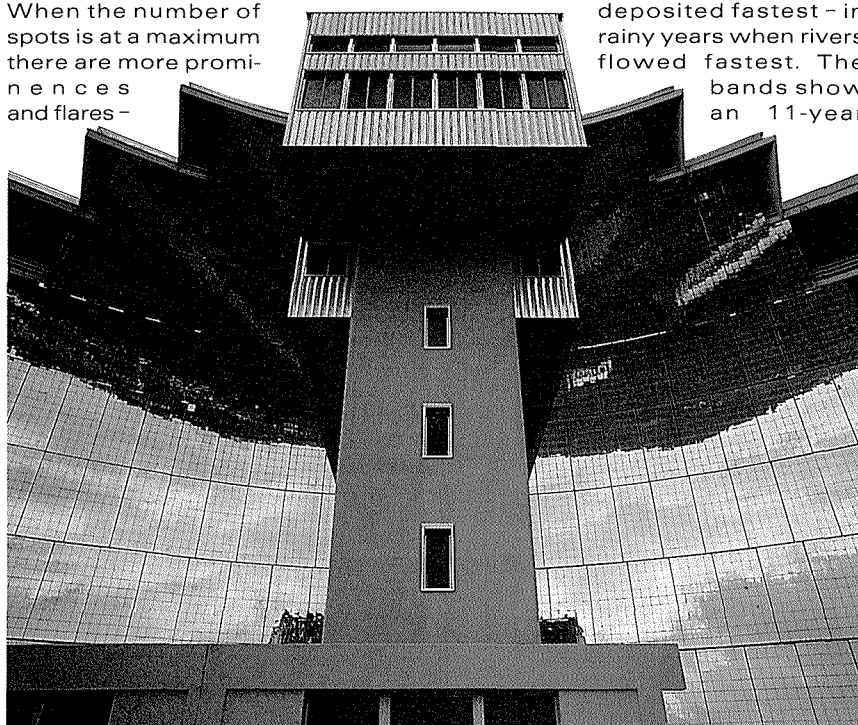
Some 680-million-year-old rocks from Australia were formed from mud and silt deposited in shallow waters. Very thin reddish bands in the layers are thicker where the mud was deposited fastest - in rainy years when rivers flowed fastest. The bands show an 11-year

The Sun dwarfs the planets of the solar system. Shown approximately to scale here they are (from left to right): Mercury, Venus, Earth, Jupiter, Saturn, Uranus, Neptune and Pluto.

molecules contain only two. When ultraviolet radiation from the Sun passes through the atmosphere, the shorter-wavelength part of it causes oxygen molecules to react to form ozone molecules. Much of the ultraviolet is absorbed in the process. At the same time, ozone molecules are continually broken down into oxygen again, thanks to longer-wavelength ultraviolet radiation, which is also absorbed in the process.

☉ Damaging chemicals

In 1985, scientists found that the ozone layer was thinning out over Antarctica every spring. This thinning, which intensified every year between 1985 and 1994, has also been observed to a lesser extent in the Arctic. It is blamed on chemicals called chlorofluorocarbons, or CFCs, which are used in such things as aerosol spray cans and refrigerators. In the atmosphere, the CFCs break down to produce chlorine, which damages the ozone layer by breaking down ozone molecules. CFCs are being rapidly phased out and substitutes are being sought for use in such products.



ZEFA

France's solar furnace in the Pyrenees collects the energy of the Sun with a series of huge mirrors and focuses it to a single point, just like a magnifying glass. This produces the temperatures you would find inside a conventional furnace.

or explosions on the surface.

The magnetic fields associated with the spots change their direction between one 11-year cycle and the next. So the Sun's cycle is really 22 years long - the time between sunspot maximums of the same magnetic direction.

Waves of suicide, wars and stock market crashes have all been linked to the solar cycle but no convincing explanation of why this should be has been advanced. However, it has been established that sunspots affect the weather. The rings in a tree trunk show the annual growth of that tree.

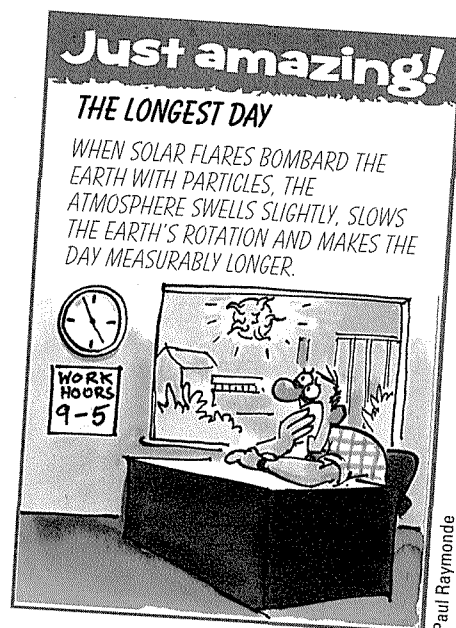
variation. And temperature records between 1855 and 1985 show a 22-year cycle that keeps step with that of the Sun's activity.

The Sun is the source of all life on Earth. The energy of sunlight is used by the leaves of plants to build up foodstuffs for themselves and by animals when they, in turn, eat the plants. The Sun also maintains the comfortable temperature range in which life can survive.

But the Sun also poses hazards to human beings. Invisible infrared and ultraviolet waves from the Sun pass through the atmosphere. Infrared waves are felt as heat. Ultraviolet waves can cause the skin to 'burn'.

☉ The ozone layer

Fortunately, most ultraviolet radiation is blocked by the ozone layer 20-35 km up in the atmosphere. Ozone is a gas whose molecules consist of three atoms of oxygen - ordinary oxygen



Paul Raymond

PROFILE

The Sun was born five billion years ago from a swirling cloud of gas and dust, like those that can still be seen throughout the Galaxy. The cloud slowly collapsed under its own gravity. As it did so, energy was released that heated the core of the cloud. For perhaps 50 million years the Sun continued like this as a protostar – its heat and light gradually blowing away the surrounding outer layers of the cloud

Average distance from Earth
Diameter at equator
Time of revolution
Mass

Average density

Density at centre
Surface gravity
Escape velocity
Surface temperature
Core temperature

149.6 million km
1,392,000 km
25.4 days
1,989 trillion trillion tonnes (332,800 x mass of Earth)
1.41 x density of water (Earth's density is 5.5 x density of water)
160 x density of water
27.9 x Earth's surface gravity
617.7 km/s
6,000°C
15 million degrees C

which formed the planets. Then, when the temperature at the centre reached about 10 million degrees Celsius, nuclear reactions were triggered and the Sun became a true star.

The Sun is an average star, one of a

hundred billion in the Galaxy. It has about another five billion years to go before it starts to run out of the hydrogen that fuels its central core. It will then start to consume the helium that will have accumulated, forming heavier nuclei of such elements as carbon and oxygen. As the helium runs out, it will start to use up these heavier nuclei in turn. As it does so, it will cool. The Sun will swell to become a type of star called a red giant, which will be about 10 per cent brighter than it is now. In 1994, a group of American astronomers estimated that in 1.1 billion years' time the Earth will be scorched, losing its atmosphere and oceans. Life will cease to exist.

☉ White dwarf

After some billions of years as a red giant, the Sun will become unstable, occasionally being rent by explosions and throwing off shells of gas – probably destroying what is left of the Earth. Finally, it will shrink to become a dim white dwarf star, the size of the Earth, and fade away into obscurity.

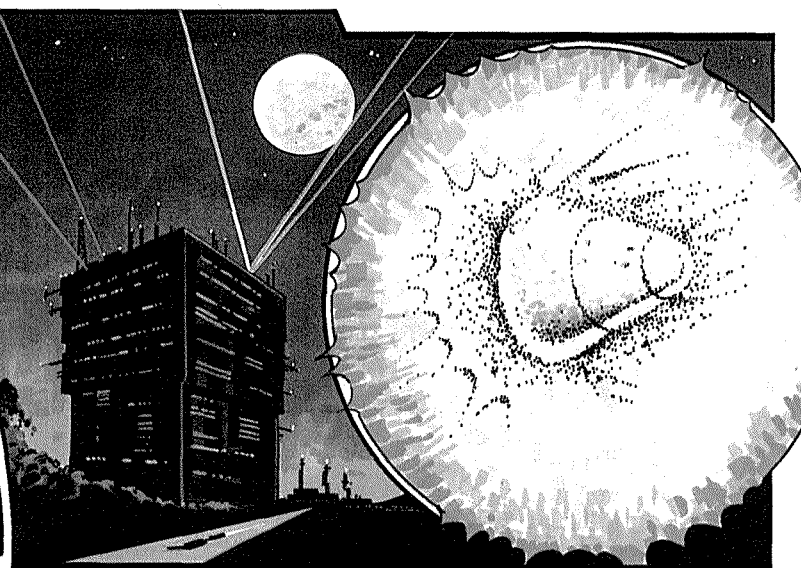
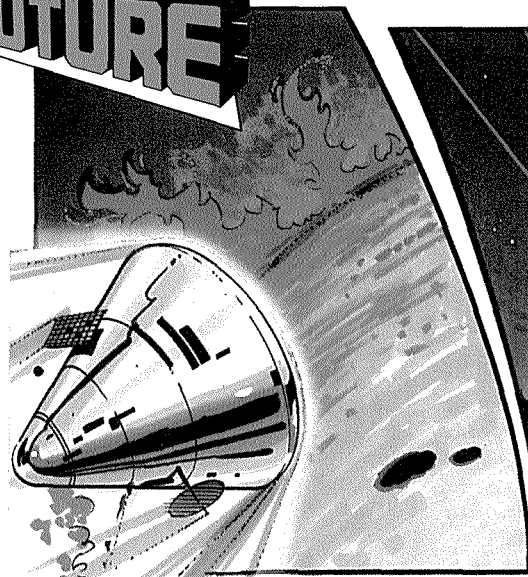
Dr Fred Espenak/Science Photo Library

NASA/Science Photo Library

The solar corona pictured by a coronagraph on the Solar Max satellite. The colours denote the intensity of light – brighter areas are blue. Normally it is impossible to see the thinner, fainter corona unless the bright body of the Sun is blocked out by a coronagraph or by the Moon during an eclipse of the Sun (above).

INTO THE FUTURE

SUN PROBE



▲ A Space probe could one day be sent right into the Sun itself. It would have to have a mirror-like surface to reflect the Sun's heat.

▲ Data would have to be sent back to Earth by laser beam, since interference near the Sun would be too great to pick up a radio signal.

▲ The probe would finally be evaporated by the great heat of the Sun – but only after it had passed through the outer layers that give off light.

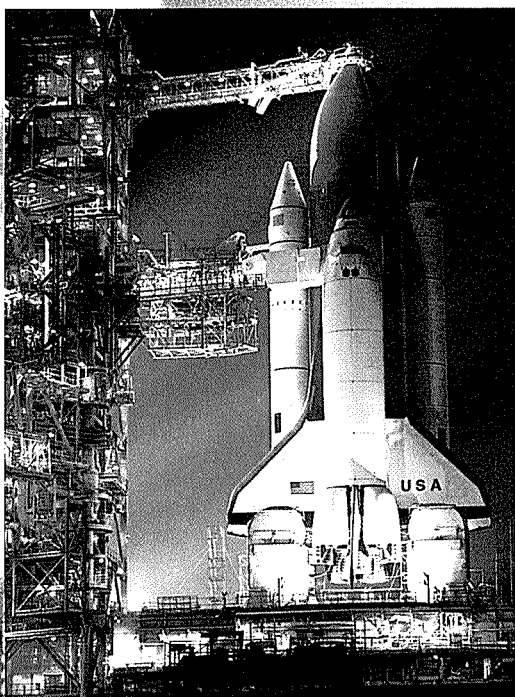
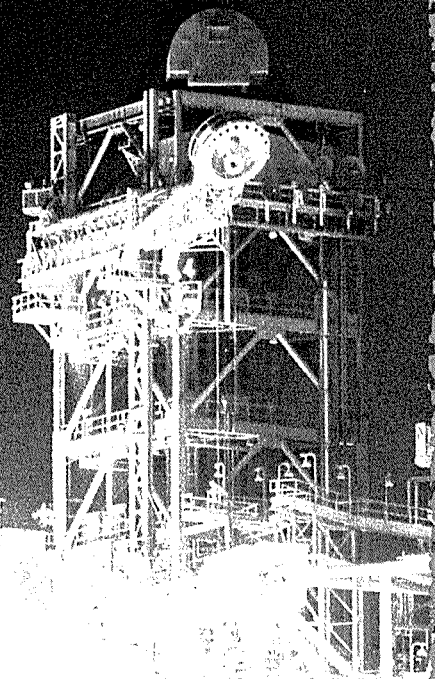
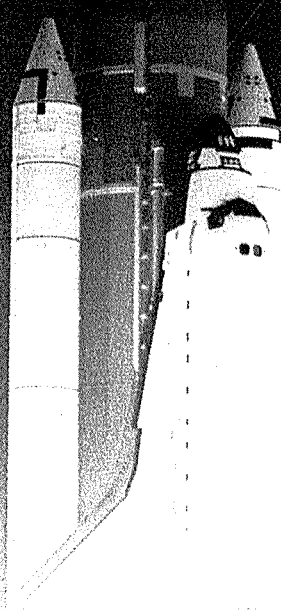
BLAST OFF

HOLDING A ROCKET STEADY before take-off, the launching gantry serves as the umbilical for both the astronauts inside and the technicians outside. The largest and most complex launch pads in use are those that service the American Space Shuttle

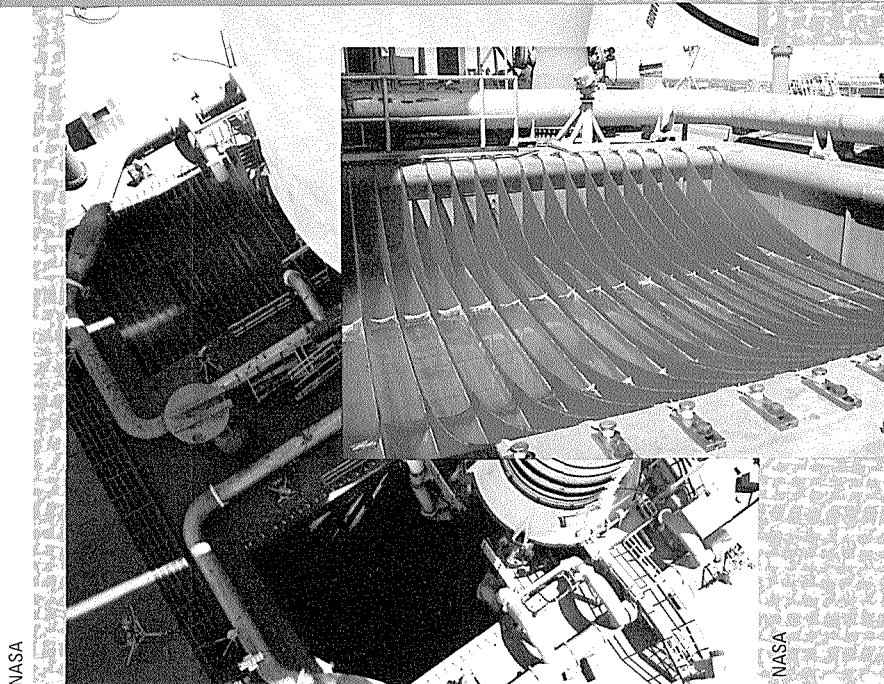
After returning to Earth, a US Shuttle is prepared for its next mission inside the 160-metre-high Vertical Assembly Building at Kennedy Space Center in Florida. Here, the orbiter is mated to its external fuel tank and twin solid-fuel rocket boosters, then placed on a Mobile Launcher Platform (MLP). This massive steel structure, 8 metres high, 49 metres long, and 41 metres wide,

The Fixed Service Structure provides access to the Space Shuttle. The Orbiter access arm and the arm that holds the beanie cap are lowered on tracks.

NASA/Science Photo Library



LAUNCH ACOUSTIC SUPPRESSION SYSTEM



During launch, the tremendous noise from the Shuttle's engines could reflect off the pad and damage the Orbiter. The high level of low-frequency noise could also damage the payload as this is carried much closer to the pad than in other rockets. To prevent this happening an acoustic suppression system is used whereby huge amounts of water are sprayed over the launch area by six conical steel castings. These castings are known as 'rainbirds' and each one is approximately twice the height of an average person.

The water is pumped from a 1.35 million-litre tank, 88 metres off the ground, at a rate of 67,600 litres per second just before the main engines are started. The resulting cushion of water absorbs much of the sound and sound-generated vibration and can also act as a fire extinguisher in the event of an accident. During test firings of the main engines or following a launch abort, the deluge also cools the back end of the Shuttle.

weighing 3,733 tonnes, serves as a portable launch pad for the Shuttle. The MLP is carried to one of two nearby launch sites at Cape Canaveral on the back of a giant crawler-transporter known as the 'mighty tortoise'.

Each Shuttle launch pad is roughly

the liquid oxygen vent system at the top of the tank from developing an ice coating that could damage the spacecraft during take-off.

The Shuttle is secured to the MLP by eight attach posts, four on each solid rocket booster. Upon launch, ex-

work levels. Its main purpose is to provide a germ-free environment for transferring satellites and other payloads from their protective canisters to the orbiter's cargo bay.

Deflector system

The MLP fits over a thick concrete slab in the centre of the launch pad called the hardstand. The hardstand's most important feature is the flame deflector system – a trench, 149 metres long, 17 metres wide, and 12 metres deep. At the bottom of the trench is a 450-tonne block of steel, coated with materials that flake off at high temperature, in the shape of an upside-down 'V' with curved sides. At blast-off, the exhaust from the Shuttle's main engines and boosters pours down through three openings in the MLP and is guided away horizontally by the deflector system.

The Ariane 401 rocket with its two liquid propellant boosters at the European Space Agency's launch base. The rocket stands 60 metres tall and can lift payloads of 1,900-4,800 kg.

equivalent to the size of three football fields. The most prominent features of each pad are the Fixed Service Structure (FSS) and the Rotating Service Structure (RSS).

The FSS is a huge, square tower, 75 metres tall, with 12 work levels at six-metre intervals. Swing arms provide access for astronauts, ground crews, and equipment.

Access arms

One specialized swing arm, called the Orbiter Access Arm, is connected to the orbiter's crew hatch. It has a special room on the end known as the 'white room' because of its germ-free atmosphere. The arm can swing from a fully extended to a fully retracted position in 30 seconds. It remains attached to the orbiter until seven minutes before launch, and can be used as an emergency exit by the crew.

Another important arm has a small round dome on the end, known as a 'beanie cap'. Measuring four metres across, the beanie cap clamps on top of the external fuel tank and warms it with heated nitrogen. This prevents



plosive nuts fire, releasing huge linking studs between the boosters and the attach posts on the MLP.

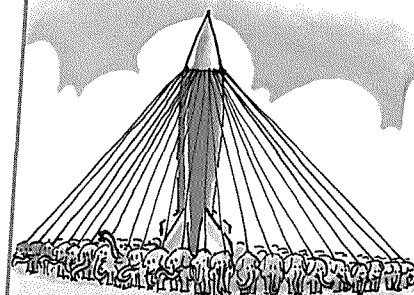
The other main component of the launch complex, the Rotating Service Structure, is hinged to one corner of the Fixed Service Structure and rotates on a special track embedded in the pad. It is 31 metres long, 15 metres wide, and 39 metres high.

The RSS also has a number of

Just amazing!

TALL AND MIGHTY

THE TALLEST LAUNCH TOWER EVER BUILT
– 136 METRES HIGH – WEIGHED 4,808
TONNES – EQUIVALENT TO THE WEIGHT
OF 960 ELEPHANTS.



Paul Raymonde

-  DRY SEAS OF MARS
-  OCEANS UNDER ICE
-  SEAS OF AMMONIA

CELESTIAL SEAS

The Earth's surface is seven tenths sea. But if Earth were slightly closer to the Sun, the oceans would boil.

SEEN FROM OUTER SPACE, the Earth's most notable feature is its colour – blue, the colour of the oceans. But the Earth is not the only planet in the Solar System to have seas.

Venus has clouds – a haze of ice crystals. But the atmosphere contains less than half a per cent water vapour and the rocky surface is much too hot – at 450° C – to sustain an ocean.

There are clouds on Mars too, clouds of water vapour much like those on Earth. Mars also has polar ice caps that advance and recede with the seasons. Under the surface too there may be ice in the form of permafrost, like the frozen subsoil found in the polar regions of Earth.

Martian canyons

On the surface of Mars there is evidence of erosion in the shape of enormous canyons, apparently cut by flowing water. Although water can only exist there now as ice or water vapour, in the past the Martian atmosphere may have been thicker, dense

The first Moon landing was in the Sea of Tranquility. This is not a sea of water, but a sea of rock. There may be water on the Moon, locked up in the rocks or frozen near the poles.

enough to allow liquid water to flow across the face of the planet cutting out these huge channels.

Thousands of kilometres below the swirling clouds of Jupiter, probably lies the surface of a dark, thick sea of liquid hydrogen, lit only by lightning bolts. This huge body of liquid hydrogen may extend tens of thousands of kilometres down until it meets a small, hard core at the planet's centre.

One of the moons of Jupiter, Europa, has a smooth surface covered with ice 75 to 100 km thick. Between the layer of ice and Europa's rocky surface there may well be seas of liquid water. Although Europa's surface is

far colder than the chilliest Antarctic night, its interior is probably quite warm. Heat produced by the decay of radioactive elements deep inside the moon may have melted the ice. There was certainly water on Europa at one time. Huge fissures can be observed in the surface where water has penetrated cracks in the rock and frozen.

Viking halls

Another of Jupiter's icy moons, Callisto, may have liquid water beneath the surface as its density is only 1.8 grams per cubic centimetre, less than twice that of water. But its surface is frozen with a daytime

Hasler & Pierce/NASA, GSF/SPL

NASA/Science Photo Library

temperature of -120°C , dropping to -190°C at night.

Its surface does have two large formations that look like the circles of ripples formed when you drop a pebble in water. Like the craters of our Moon, they seem to have been formed by impact. Perhaps the impact there was so severe that the icy surface melted for a moment, then froze again leaving the ripply pattern in the short-lived sea frozen there forever.

The two circles are known as Asgard and Valhalla. Asgard is the mythical home of the Norse gods and Valhalla is the great hall where Odin feasted with dead Viking heroes.

Julian Baum/Science Photo Library

There are also indications that the icy surface of Saturn's brightest moon Enceladus thaws occasionally. In certain areas there are no craters at all, as if ice has melted and refrozen into a smooth surface.

Another of Saturn's moons, Titan, is shrouded by clouds of natural gas. Scientists believe that drizzle and rain from these clouds would cause a global ocean 1 km deep. However, radar probes indicate that there are areas of dry land as well as huge seas of liquid methane.

Glacier action

Two of Uranus's moons – Miranda and Ariel – have traces of erosion, but probably due to ice warm enough to flow like a glacier, rather than water.

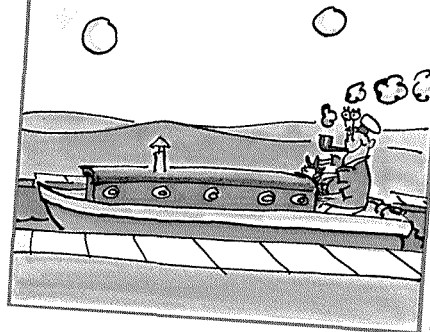
Before the American Space probe Voyager reached Neptune, it was thought that one of its moons, Triton, had seas of liquid nitrogen on its surface. But at -236°C , it was too cold even for that.

Elsewhere in Space, where condi-

Just amazing!

MARTIAN MASTERBUILDERS

A CENTURY AGO, SOME OBSERVERS SAW FINE LINES ON MARS, WHICH THEY THOUGHT WERE CANALS DUG BY MARTIANS. BUT THEY TURNED OUT TO BE AN OPTICAL ILLUSION.



Paul Raymond

The Valles Marineris – one of the Martian canyons. These show signs of erosion by water some millions of years ago.



Uranus seen from its moon **Miranda**, as depicted by an artist. The surface of Miranda shows signs of erosion, probably by flowing glaciers.

Jupiter's moon Io may have seas under its frozen surface. Saturn's cloud-shrouded moon **Titan** (below) may have seas of liquid methane.

PLANETSCAPING

Planets on which no liquid water exists today could be engineered in the future to have rivers, lakes and seas. This would be done by a technique called terraforming. In the case of Mars, for instance, dark rock could be mined from the two small Martian moons, Phobos and Deimos. Scattered over the poles of Mars, this material would absorb more of the Sun's heat and so cause the polar caps to melt. The melt water could be used to grow plants and, by evaporation, to thicken the atmosphere. The greenhouse effect of the increased water vapour in the atmosphere would warm Mars further, perhaps unlocking huge reserves of water that may currently lie frozen deep underground.

tions are right, there may be planets with seas of ammonia. These would seem bizarre by Earth standards. The temperature of an ammonia sea, at normal atmospheric pressure, could be between -33.4°C and -77.7°C . Stranger still, any icebergs in such a sea would sink to the bottom. While ice is lighter than water and floats, frozen ammonia is heavier than liquid ammonia and so sinks down.

Seas of poison

On other worlds, oceans might form from sulphur dioxide. Normally, on Earth, this is a poisonous gas. But between -10°C and -72.7°C it exists as a liquid. Nitrogen, methane and other gases could also form sub-zero seas or lakes on worlds orbiting other stars.

So it turns out that the Solar System is not a good place for oceans. Water only occurs in liquid form in a very narrow range of temperatures – just 100° , between 0°C and 100°C at Earth's atmospheric pressure. Most planets and moons have an atmosphere so thin, or non-existent, that water can only exist in the form of ice or water vapour and no seas, as we know them, could form.

NASA/Science Photo Library

US Geological Survey/Science Photo Library

JPL/NASA



PIIONEER CRAFT

O U T

WORLD

DIGITAL PHOTOS

LASER SHOWS

O F T H I S

AS YOU READ THIS, FOUR robot spacecraft are heading towards the stars, carrying with them pictures and sounds of the planet Earth. If intelligent aliens ever find them, they will be given an insight about human beings and be able to detect our whereabouts.

Two of these interstellar probes, Pioneers 10 and 11, became the first spacecraft to fly by the giant outer planets Jupiter and Saturn. Launched in 1971, Pioneer 10 made its rendezvous with Jupiter in December 1972 before heading on a path that carried it out of the Solar System. Its sister craft, Pioneer 11, travelling one year behind, was redirected by Jupiter's gravity pull to an encounter with Saturn in September 1979.

Coded greetings

Each Pioneer carries a gold-anodized aluminium plaque, 15 cm across, fixed to one of the antenna support struts. Coded information on the plaque shows the position of the Sun in the Galaxy, together with the nine planets that orbit the Sun and an arrow to indicate that the spacecraft came from Earth.

Alongside is a drawing of a man and a woman standing in front of the probe. The man has his right hand raised in a gesture of friendship.

The twin Voyager probes, launched in 1977, have a far more

Voyager 2 is depicted during its close encounter with Uranus in 1986. The great gas giants' unique in that it lies 98° to the plane of the Solar System.

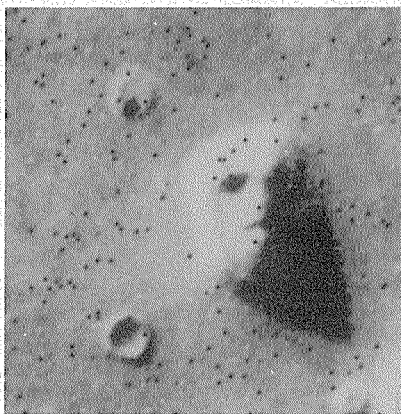
The Great Red Spot on Jupiter is a massive storm that has been raging for over 200 years. It is the only storm on the planet that has been observed from Earth. The Great Red Spot is also shown in the image, along with other cloud structures and vortices.

NASA/Science Photo Library

Julian Baum/Science Photo Library

THE HUMAN FACE OF THE RED PLANET

One amazing picture of the surface of Mars sent back to Earth by the Viking mission, in 1976, shows what looks like a giant human face. Measuring about three kilometres across, the face is thought by most scientists to be just a trick of the light. But in 1988, studies by an American computer programmer suggested that the object might continue to appear as a face if viewed from other directions. It seems to have a nose, two eye sockets and even a set of teeth in its mouth. Future spaceprobes to Mars will no doubt take a closer look to see if the face really is an alien art form or just an unusual natural feature.



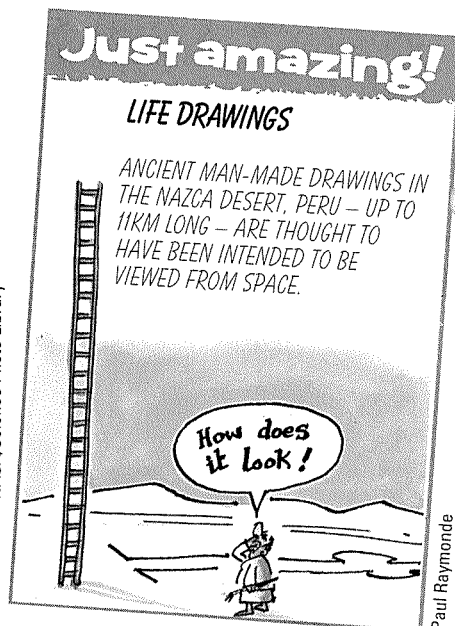
NASA/Science Photo Library

sophisticated message aboard for any extra-terrestrials that may discover them. A phonograph has been fixed to the side of these spacecraft. This contains 90 minutes of the world's greatest music, greetings in 56 languages, and 118 pictures of the

Earth and its inhabitants. A stylus is also provided together with instructions on the protective covers on how to play the record.

One of the problems faced by the creators of the Voyager record was to decide exactly what images and sounds to include. Any intelligent aliens that may exist among the stars would probably be totally unlike us and would not understand our language. So the pictures and sounds

The pictorial plaque attached to the Pioneer spacecraft is the first man-made object to be sent out of our Solar System. From these messages intelligent extra-terrestrials should be able to calculate from where and when Pioneer 10 was launched, the average sizes of the humans that sent the craft and the craft's trajectory from Earth passing Mars and swinging by Jupiter.



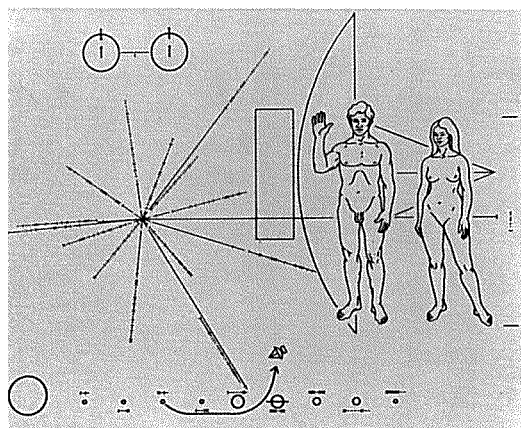
Paul Raymond

had to be selected carefully to be both clear and informative.

Among the photographs digitally encoded on the Voyager record were those of children in a school, workers in a factory, people eating a meal, an astronaut in Space, and builders putting up a house. Various animals and plants, views of the land and sea, and some of the world's most famous buildings were also included.

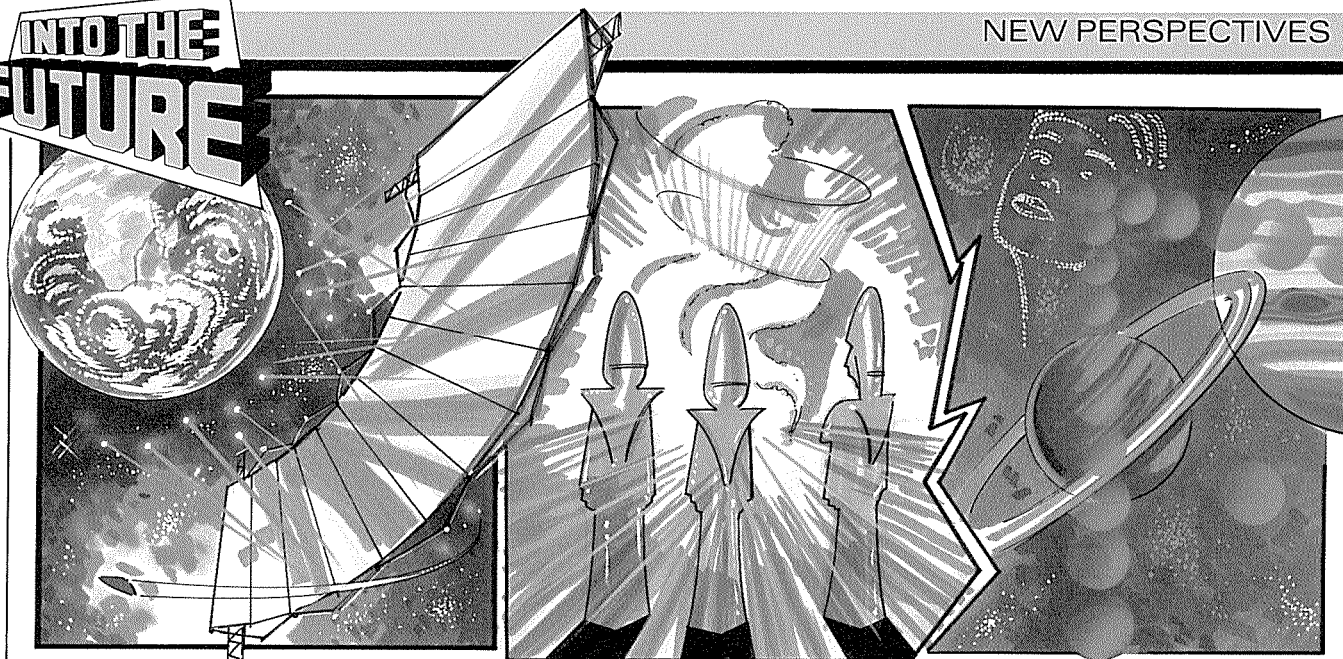
Light years away

The chances that either of the Voyager spacecraft will be found by extra-terrestrials is extremely small. If they were, it would be very far in the future. At their current speed it would take the Voyager craft about 100,000 years to reach even the nearest star beyond the Sun!



INTO THE FUTURE

NEW PERSPECTIVES



▲ Giant mirrors of wafer-thin aluminium foil may be sent into Earth orbit and unfolded to reflect laser light, beamed from Earth, to form spectacular shows.

▲ Intelligent aliens and colonists of other planets may have no concept of art for arts' sake, or may have developed art forms totally unlike anything on Earth.

▲ In the remote future, entire planets or star systems could be engineered into cosmic works of art - viewed from Earth by millions of people at the same time.

Joe Lawrence

SPACE JUNK

SPACE IS FULL OF RUBBISH. Far from being a vacuum, the Space near Earth is teeming with all kinds of junk – billion-year-old bits of debris left over from the formation of the planet and more recent trash left over from the Space programmes.

Since the first satellite, a Russian Sputnik, was launched in 1957, more than 16,000 man-made objects have been shot into Space. Most have fallen back to Earth and burnt up in the atmosphere. But 7,200 objects still remain in orbit, tracked by the North American anti-missile radar system. Many are rocket casings and dead satellites. Only 300 are working satellites. Such radar systems, however, can only track objects larger than 10 cm across. Scientists believe that there are more than 3.5 million pieces of debris orbiting the Earth that are too small to track.

❶ Satellites

At the beginning of the Space programmes, hundreds of short-lived spy and weather satellites were launched. When they were no longer needed, they simply stayed in orbit, as useless pieces of junk.

Communications satellites placed in a geostationary orbit, above the Equator, orbit the Earth once a day. This orbit is crowded with more than 300 satellites – and with thousands of tiny pieces of debris released when the satellites

Collisions in Space are an ever-present danger, when 3 million kg of man-made materials orbit the Earth. Scientists predict that in ten years time the total may be 4 million kg.

David Weeks

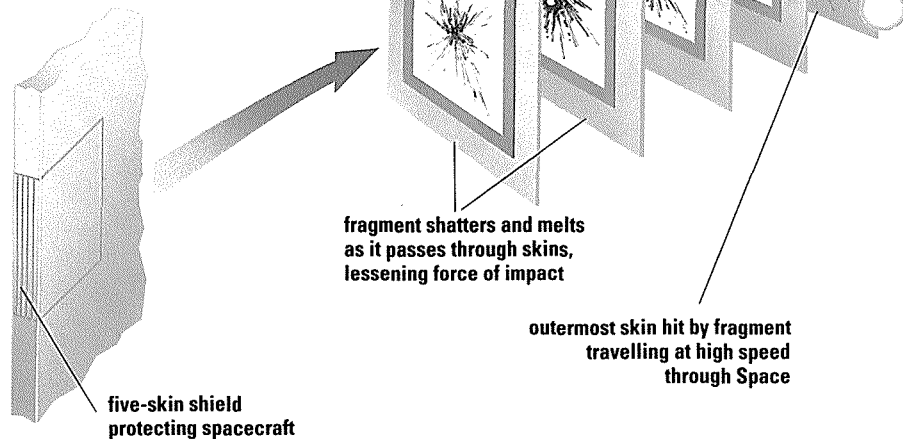


separated from the rockets that launched them.

Early in their life, the satellites carry fuel and can be nudged and repositioned to avoid other satellites. When the fuel is exhausted, they can no longer be manoeuvred out of the way. Satellites in a geostationary orbit are

Space junk in orbit around the Earth. Over 7,000 man-made items more than 10 cm across have been identified by American radar systems.

Space Shield



junk. The scientists who examined the disabled satellite found that it had also been damaged by tiny particles of frozen human urine, jettisoned into orbit on earlier manned Space flights.

The danger of collisions with debris will become even more of a problem when the Space station *Freedom* is launched sometime in the late 1990s. With a large Space station orbiting for decades, a collision would be almost inevitable.

Collision course

At orbital velocities, each particle of debris delivers an impact of four times its weight of TNT. A 5-cm fragment travelling at 24,000 km/h would strike the Space station with the force of a steel safe dropped from a tenth-storey window. *Freedom's* high-

A foot restraint escaped into Space during a spacewalk by two astronauts from Space Shuttle Challenger. Luckily, astronaut Bruce McCandless was able to retrieve it later.

Five layers of ceramic fabric form a shield that absorbs, without fragmenting, bits of orbiting junk, so debris from the impact does not float into Space.

SHOOTING STARS



Man-made debris falling from the skies is not the only danger. Every day, some million meteors, or 'shooting stars', hit the Earth's atmosphere. Thousands of millions of micrometeors (tiny flecks of Space dust) burn up in the outer atmosphere. Sometimes, larger objects reach the surface. Tonnes of dust from Space settles on the Earth each day. Larger meteorites hit the ground more rarely – only 14 or so large craters have been discovered on the Earth's surface. One is Meteor Crater in Arizona, USA (above), which measures 1.2 km across. An arc of islands in Hudson Bay, Canada, may be part of the rim of a crater 440 km across created by the impact of a giant asteroid. As recently as 1908 a comet hit a remote area of the USSR with the force of a nuclear explosion.

pressure storage tanks, which would explode on impact, make the Space station very vulnerable.

Scientists at the American Space agency NASA have been working on the problem. One

Andrew Shaw

Telegraph Colour Library

NASA/Science Photo Library

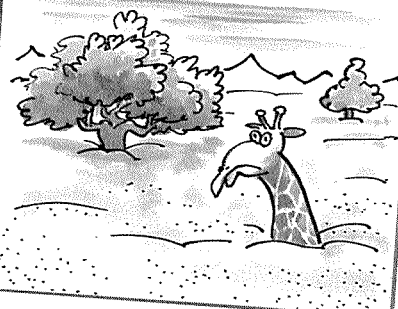


A US F-15 aircraft launches an anti-satellite missile (below) high in the atmosphere. Weapons tests account for much of the man-made debris in Space. Some 350,000 fragments were scattered through Space when, in 1984, the Solwind satellite was destroyed in just such a test.

Just amazing!

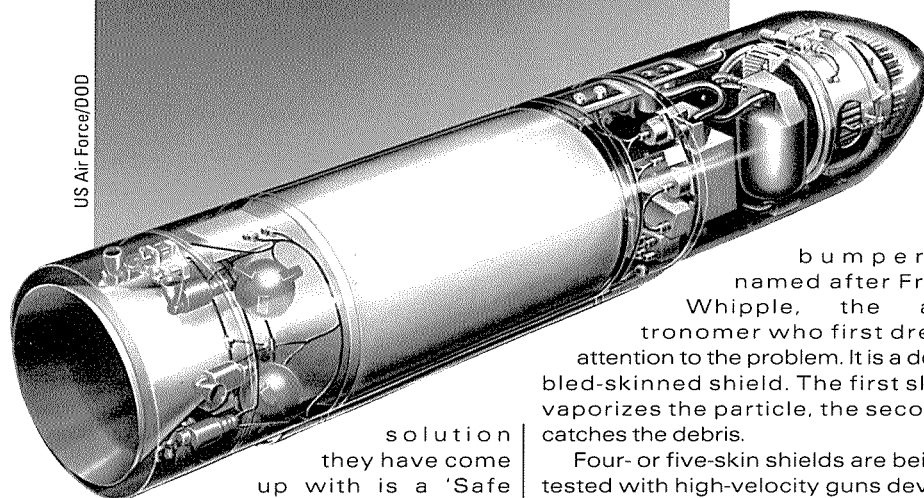
DUSTING OVER

AN ESTIMATED 4 MILLION TONNES OF SPACE DUST SETTLES ON THE EARTH EACH YEAR. IF UNDISTURBED SINCE THE EARTH WAS CREATED, IT WOULD HAVE FORMED A LAYER OF DUST SOME 3 METRES DEEP.



Paul Raymond

US Air Force/DOD



bumper, named after Fred Whipple, the astronomer who first drew attention to the problem. It is a double-skinned shield. The first skin vaporizes the particle, the second catches the debris.

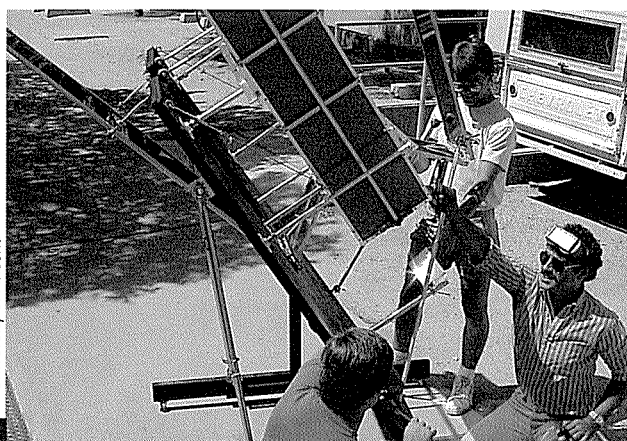
Four- or five-skin shields are being tested with high-velocity guns developed by NASA to simulate an orbital

solution they have come up with is a 'Safe Haven' - a fortified module

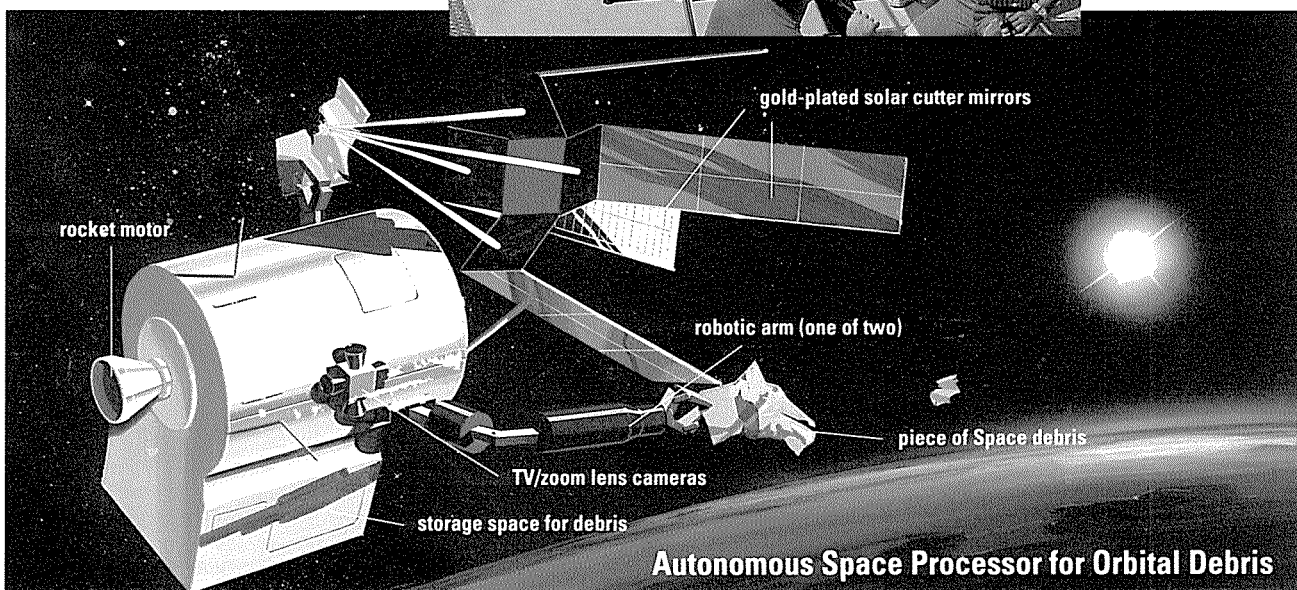
that could survive any collision. But to make it strong enough it would have to be very heavy, and it would be expensive to put into orbit. Collision-warning systems have already been put to the test on the Space Shuttle, but it would be impracticable to manoeuvre the Space station out of the way each time a piece of debris comes too close.

Shields are also being developed. From the beginning of Space travel, it was clear that a single skin could be easily penetrated by just one tiny meteoroid. Spacecraft have been shielded with so-called Whipple

University of Arizona

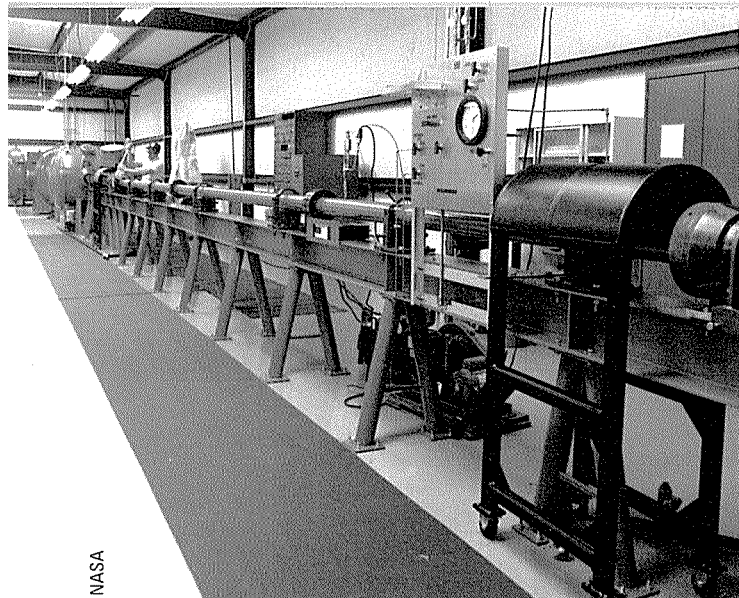


In the future, Space debris might be disposed of by an ASPOD. Developed by American scientists (left), it grabs hold of chunks of orbiting rubbish and cuts them into smaller pieces so they can be stored until the ASPOD re-enters Earth's atmosphere and burns up.



Stan North

Autonomous Space Processor for Orbital Debris

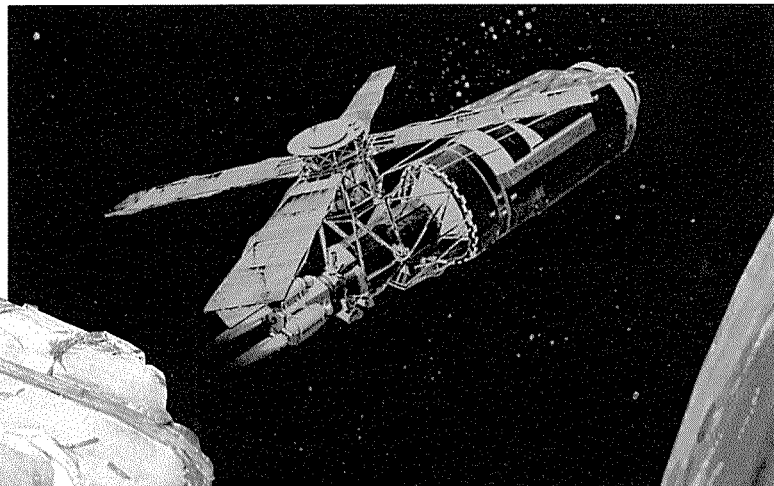


NASA

Spacecraft shields are tested by a hypervelocity gun. Compressed hydrogen propels a particle along the launch tube and into a shield in the target chamber.

orbiting refuse collector called the 'Autonomous Space Processor for Orbital Debris'. This has radar and infra-red eyes to locate debris. Two robotic arms will grab the junk and cut it up by focusing sunlight through lenses into a point of light at a temperature of 700°C. The processor will then collect the fragments and move

NASA



Debris showered Australia when Skylab (above) broke up. It had been planned to boost Skylab into a higher orbit with a Teleoperator Retrieval System.

on. When it is full, it will plunge back to Earth and burn up in the atmosphere.

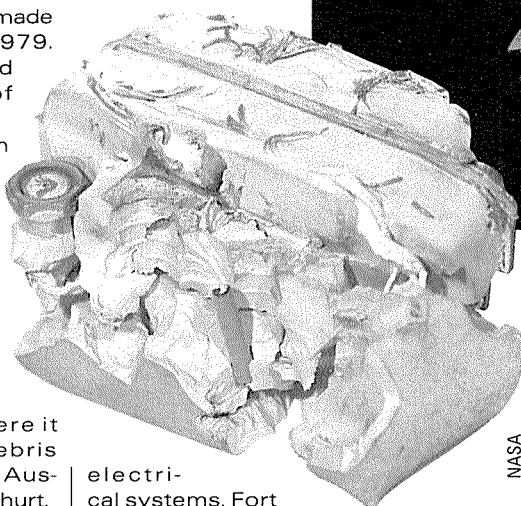
Another solution is to prevent the problem in the first place. Space agencies are now redirecting their used rocket cases upwards into Deep Space, or downward to burn up in the Earth's atmosphere. But the debris in Space already could take as long as 500 years to come down.

NASA

America's orbiting Space station, made an unexpected return in July 1979. Launched six years earlier, it had been occupied by teams of astronauts for a total of 170 days.

It was supposed to remain in orbit for ten years. However, unexpected solar activity increased the density of the Earth's outer atmosphere and, as a result, the spacecraft was bombarded by air molecules that slowed it down, even though it was orbiting at a height of nearly 400 km. This brought Skylab back into the Earth's atmosphere, where it began to break up, raining debris down on Earth. Fragments hit Australia but fortunately no one was hurt.

Worse, in 1978 a Soviet satellite, Cosmos 954, crashed back through the atmosphere, hitting Canada. Like many Soviet satellites, it had a nuclear generator on board to power its

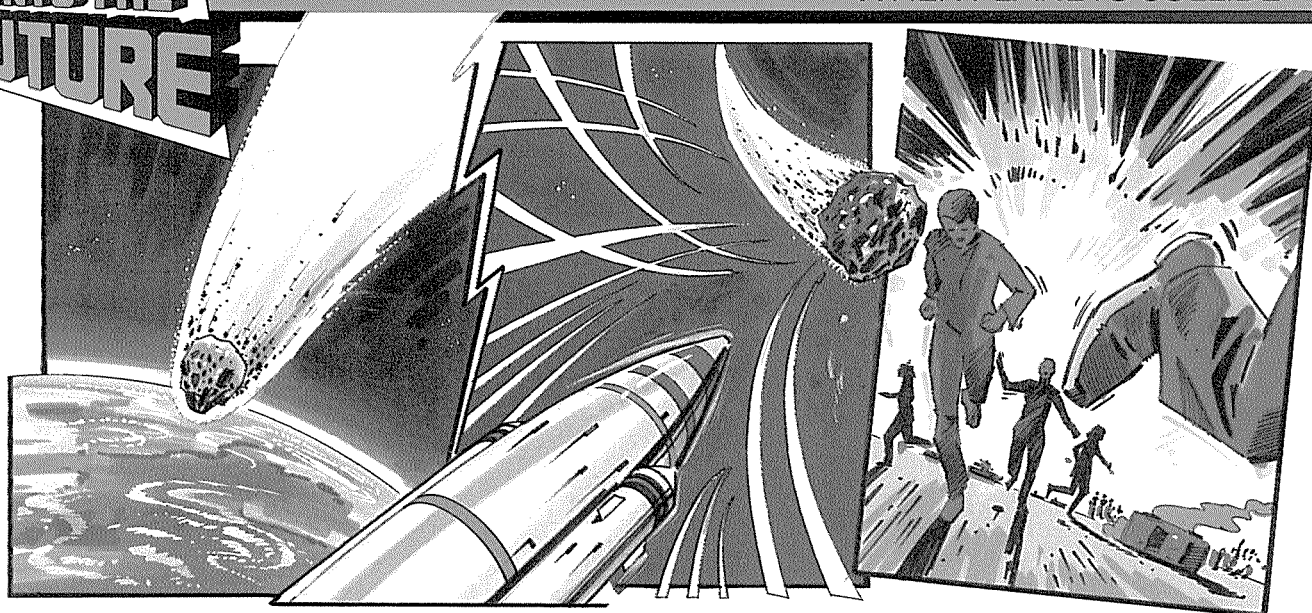


electrical systems. Fortunately, the uranium-235 core spread harmlessly across the Canadian tundra.

A group of engineers at the University of Arizona, USA, have designed a possible solution to the problem - an

INTO THE FUTURE

WHEN PLANETS COLLIDE

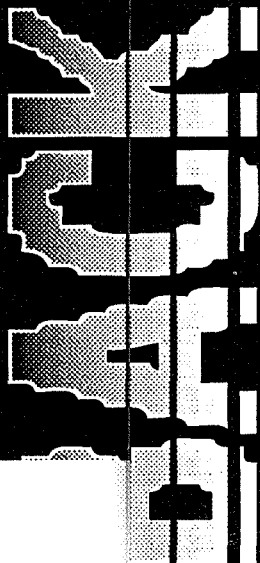


▲ The irregular orbit of Icarus, a mini-planet in the asteroid belt between Mars and Jupiter, crosses that of the planet Earth. A collision might be catastrophic.

▲ However, if Icarus were on a collision course with Earth, the asteroid, 1.4 km in diameter, could probably be deflected by hydrogen bombs mounted on rockets.

▲ An asteroid larger than Icarus - Eros, for example, which measures roughly 23 km across - would be much harder to divert. Impact might kill all life on Earth.

Joe Lawrence



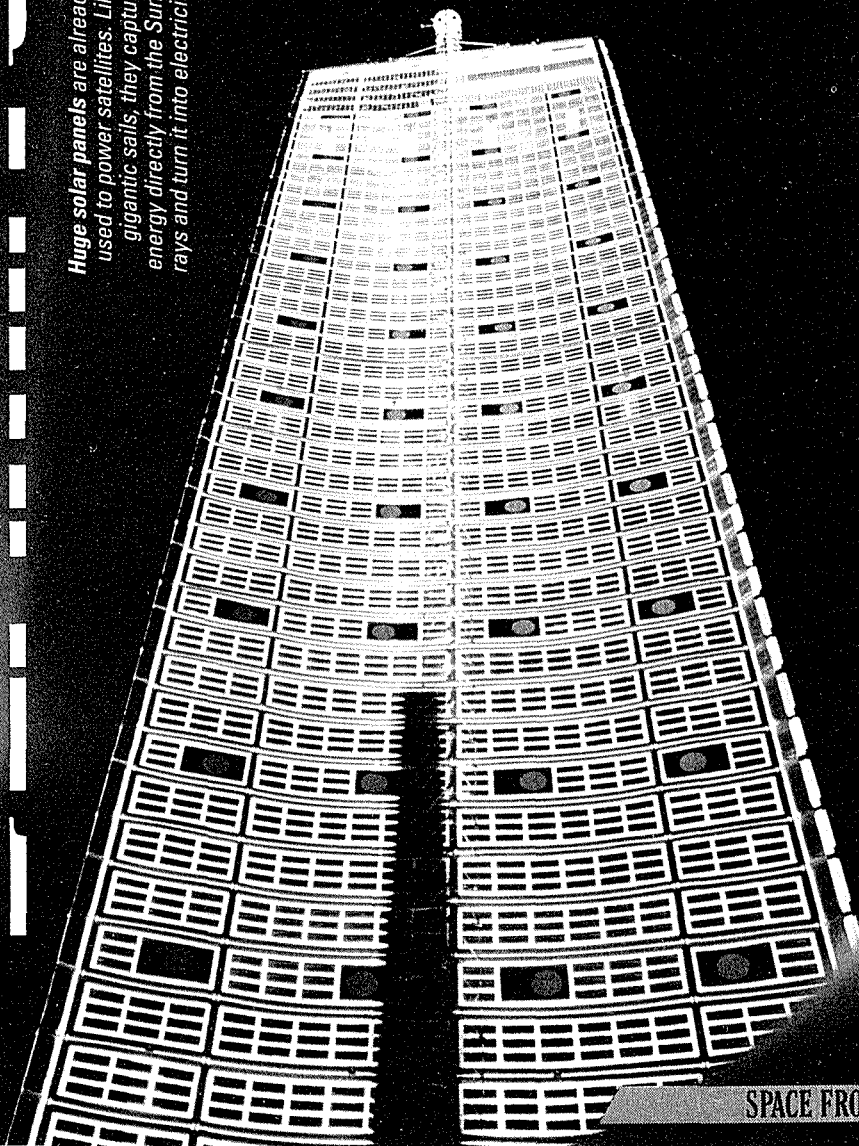
Huge solar panels are already used to power satellites. Like gigantic sails, they capture energy directly from the Sun's rays and turn it into electricity.

NEXT CENTURY, HUMANKIND will be looking out into Space for energy. Not only will they be using energy from Space to power the Earth, new forms of off-Earth power will be used to propel deep Space probes.

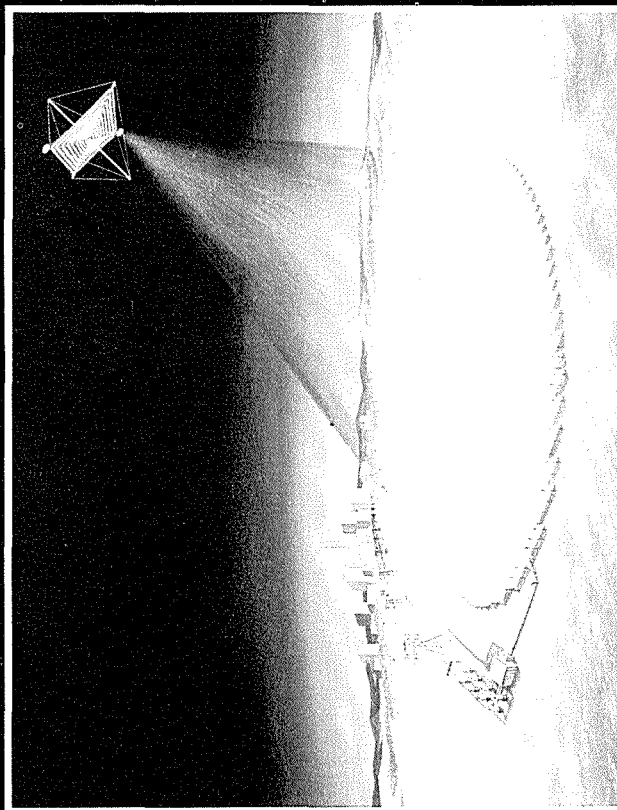
Energy from the Sun is non-polluting, free and virtually unlimited. But solar power stations on Earth cannot produce electricity at night or on cloudy days. To avoid this problem, a

huge array of solar cells, several kilometres wide, could be assembled in geosynchronous orbit, 35,900 km above the surface of the Earth.

The electricity produced by the orbiting power station would be turned into microwaves and beamed to a large receiver on the surface. These can pass right through clouds, so the beam would be able to get through day and night, whatever the weather. At the ground station, the energy in



Solar power stations, more than 8 km in diameter, could beam energy down to special ground stations on Earth using microwave links.



NASA



the microwave beam would be transformed back into electricity and used to supply homes and industry. A single array, eight kilometres across, could supply the needs of a city the size of Birmingham in the UK.

Solar energy may also be used to

push a new type of spacecraft to the outer planets. The pressure of light particles, or photons, coming from the Sun acts like a gentle wind. This wind could be trapped by spacecraft equipped with immense, gossamer-thin aluminium sails in the same way that a yacht uses a breeze on Earth.



Interplanetary race

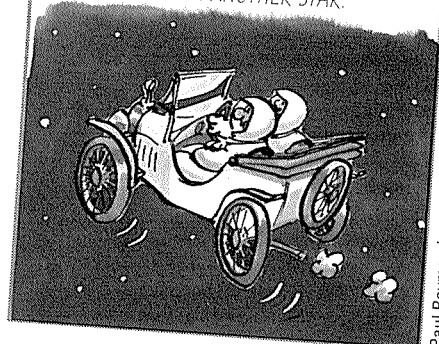
Such solar-powered craft could be used for slow, but sure, interplanetary travel. They would be launched by rocket into a high Earth orbit. They would then unfurl their sails and allow the Sun's radiation to push them towards Mars. They would weigh about 300 kg and have a sail the size of London's Wembley Stadium. It would be steered by flexing the sail so that different parts received more or less sunlight and should reach Mars in 200 to 300 days.

As you get further from the Sun,

Just amazing!

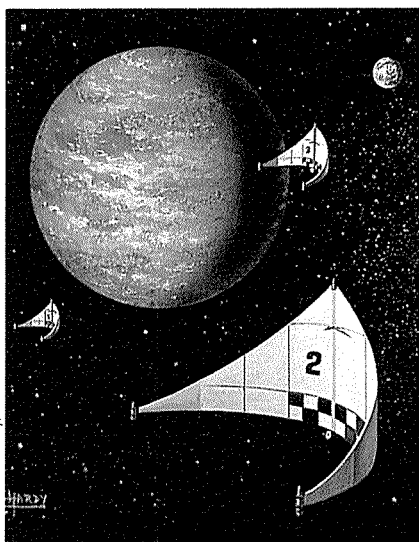
LATE ARRIVAL

FOUR SPACE PROBES ARE ALREADY HEADING OUT OF THE SOLAR SYSTEM. BUT AT THE SPEED THEY ARE TRAVELLING, IT MAY TAKE THEM 100,000 YEARS TO REACH ANOTHER STAR.



Paul Raymond

David A. Hardy/SPL



Sail power of the future – these proposed spacecraft are propelled by light emitted from the Sun. The pressure of sunlight on their thin membranes – up to a kilometre across – would power them into deep Space. The Nina (right) is bound for Mars.



the strength of solar radiation falls off. However, if a powerful laser beam, stationed somewhere in the Solar System, was trained on a photon sail, the craft could still be powered across interstellar Space.

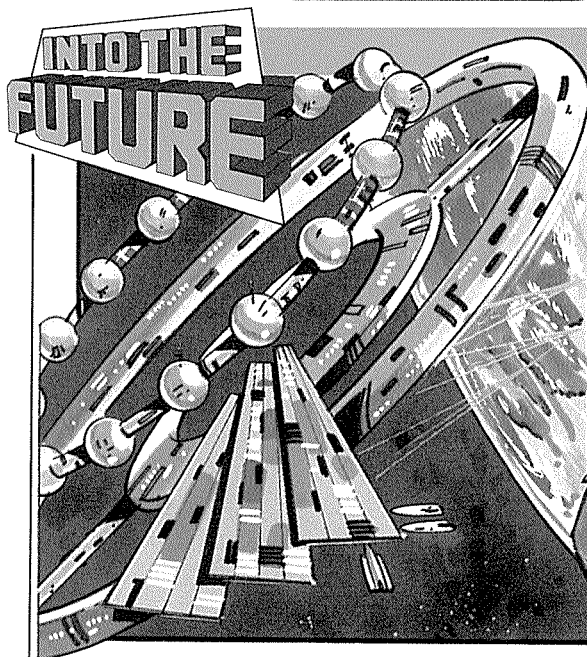
Interstellar light sailing would involve incredibly large structures. One design, for instance, calls for a sail 100 km across but only a millionth of a centimetre thick.



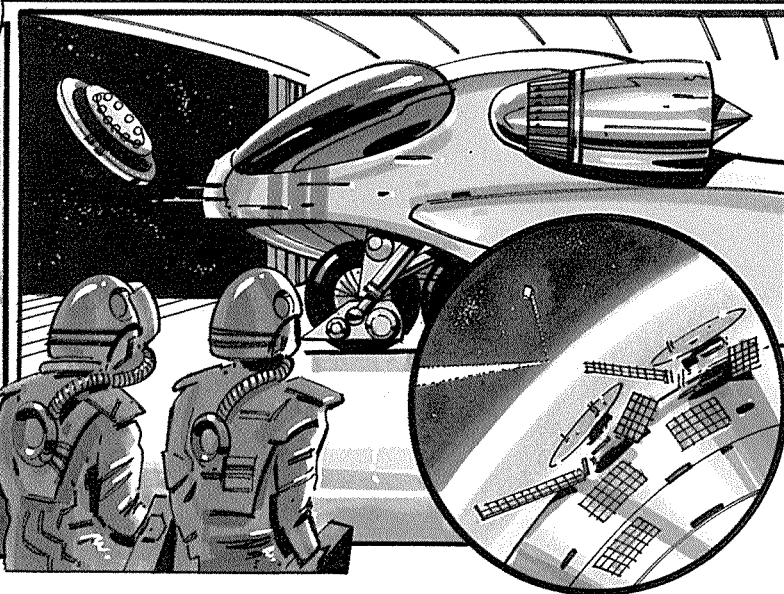
Slowing down

Cambridge Consultants

To apply the 'brakes' as the spacecraft approached its target star, the outer part of the sail would break away and move ahead of the central section. Laser light reflecting off this outer ring would then strike the central part from the opposite direction, slowing it down with the reverse thrust.



SPACE POWER



▲ Power stations in orbit could collect solar energy and beam it back to Earth. This could provide all the energy that people might need.

▲ These could easily be maintained by engineers who would travel to and fro on the Space Shuttle or one of the new generation of Space planes.

▲ However, the stations' fragile solar panels would have to be shielded from Space debris – the tiniest fragment would tear them to shreds.

Joe Lawrence



Q ZERO-G

Q SPACE SICKNESS

Q COSMIC RAYS



Patrice Loez, CERN/SPL

NASA/SPL

A permanently manned Space station (artist's impression) being developed by NASA will need to address the hazards shown by experiments in Space with biological specimens. These experiments demonstrate that fast moving atomic particles (left) can severely damage the cells of living organisms.

IN THE FUTURE, PEOPLE MAY live in Space or go on long journeys to other planets and stars. But before that can happen some serious medical problems have to be overcome.

Not least among the hazards is radiation. When on Earth, high-energy rays from Space that are dangerous to humans are blocked by the Earth's atmosphere. These include electromagnetic waves such as X-rays and gamma rays, together with streams of fast-moving, charged particles. Above the atmosphere, however, a spacecraft is continually bombarded with these tiny bullets of energy, some of which are able to pass straight through its walls.

Charged particles moving close to the speed of light pose the most

deadly threat. They can penetrate the living quarters of a spacecraft and enter an astronaut's body, destroying living cells. Exposed to sufficiently high doses, a Space traveller could develop radiation sickness or cancer.

☉ Solar storms

Within the Solar System, by far the greatest source of energy-charged particles is the Sun. In 1956, for instance, a giant solar flare released enough radiation in half an hour to give astronauts a thousand lethal doses. Fortunately, this happened before the first manned spaceflights. Future interplanetary spacecraft will need to be equipped with solar storm shelters, shielded by fuel tanks and other radiation-absorbing hardware.

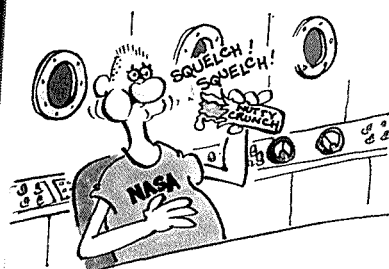
Lengthy exposure to zero-g, or

weightlessness, can also be harmful to astronauts. Without having to work continually against the downward pull of gravity, a person's muscles grow weaker. This is especially worrying in the case of heart muscles, as the heart may pump blood less effectively around the body when the astronaut returns to Earth.

Just amazing!

DISINTEGRATING DINNER

IN THE SPACE SHUTTLE, BITE-SIZED CUBES OF FOOD HAVE TO BE COATED WITH A THIN LAYER OF GELATINE TO PREVENT CRUMBS FREE-FLOATING IN THE ZERO GRAVITY.



Paul Raymond



Food onboard the Space Shuttle can be freeze-dried, irradiated and thermostabilized. The bubble of strawberry drink shows the odd properties of liquid in microgravity conditions.

Microgravity also affects the flow of blood through the body. Testing of lower body negative pressure (below) is assessing this effect, whereby blood rises to the head and chest.

NASA/Science Photo Library

Bones are also affected by weightlessness. In orbit, the rate at which new bone material is laid down slows, which means that the skeleton becomes progressively more brittle. Living in zero-g also lowers an astronaut's immunity to disease. Though it is not clear why, a person produces fewer white blood cells – an essential part of the body's defence system – when weightless.

Weightlessness

Doing the simplest jobs in Space can be surprisingly hard. This is because our ability to do delicate tasks depends largely on being able to judge the weights of different objects. Under weightless conditions, it is much harder to know how much force to exert to achieve just the right amount of movement.

More than 40 per cent of all

astronauts are sick for the first two to three days of their flight. This can mean that tasks have to be delayed or performed more slowly than usual.

The symptoms of Space sickness are like those often felt by people in a boat on rough seas – nausea, vomiting, cold sweats and drowsiness. Weightlessness, like a choppy sea, upsets a person's sense of position, movement and balance. Although an astronaut's brain and eyes may try to tell him what is up or down aboard a spacecraft, there is no gravity pull to confirm this. The resulting conflict of signals reaching the inner ear balance mechanism and being transmitted to the brain is probably what brings on the sickness.

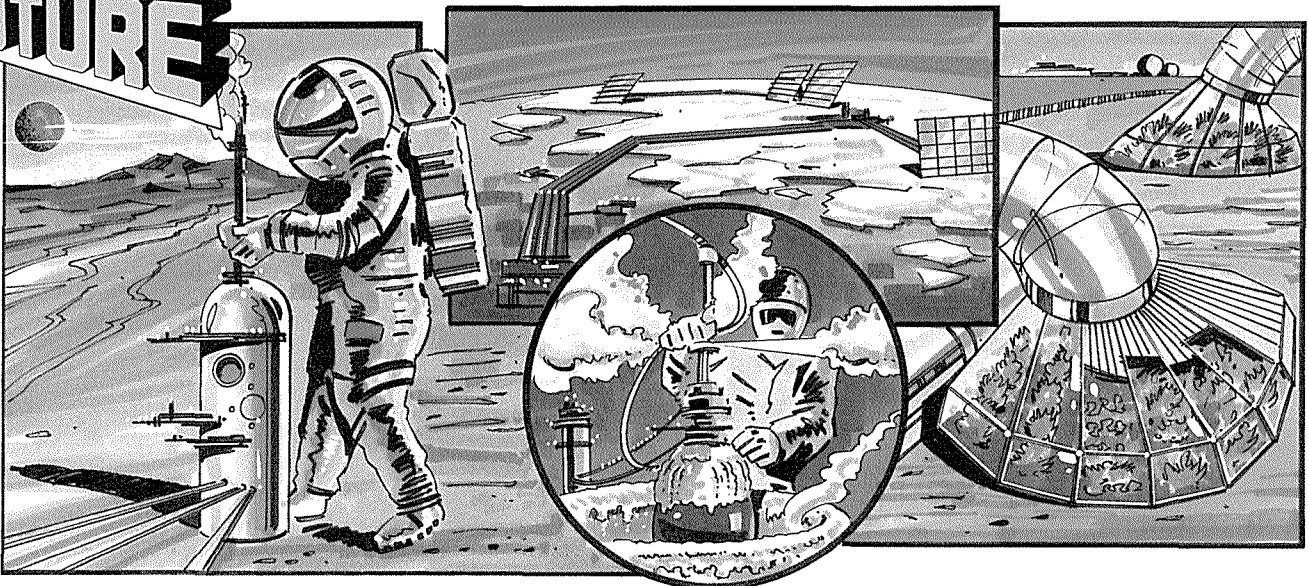
When astronaut Edwin Aldrin saw strange flashes of light during the

Apollo 11 flight to the Moon, he thought he was going mad. However, other Apollo and shuttle crews since have noticed similar flashes. Almost certainly, they were seeing cosmic rays – very high speed, charged particles from the depths of Space. Cosmic rays come to us randomly from all directions, but the Earth's atmosphere prevents them from reaching the surface. In Space, a cosmic ray can occasionally pass through an astronaut's eye causing pinpoint flashes or streaks on the retina.

NASA

INTO THE FUTURE

LIFE ON MARS



▲ Survival on Mars would not be easy. The thin atmosphere offers nothing to breathe and gives no protection from cosmic rays.

▲ Water could be melted from below the surface. Using solar power, the water could be electrolysed, providing oxygen to breathe.

▲ Although Mars contains metals that could be usefully mined, there is no nitrogen so plants could only grow in nutrients brought from Earth.

Joe Lawrence

HEAVENLY MOTION

seemingly moving backwards in the sky for short periods.

Eventually, the explanation became clear. If the Earth and these other strangely acting bodies in the sky were all revolving around the Sun all their orbits would be simple ellipses. Those bodies with backward motion were the planets beyond Earth and those which moved smoothly were the stars.

Laws of motion

The motion of the planets first gave rise to the laws of motion, developed by Isaac Newton. He came up with three fundamental principles. First, he said, anything that is not subjected to an external force will continue in a 'uniform state of motion' - that is, it will remain where it is or will continue travelling at a constant speed in the

NASA MOTION IS FUNDAMENTAL TO the Universe. Electrons move around the nuclei of atoms. The planets move around the Sun. The Sun itself moves around the galaxy. And, it seems, our galaxy has been moving through Space since the beginning of time.

Some 15 billion years ago, when the Big Bang occurred, time and Space were created. During that huge explosion, motion was also produced as the matter that eventually formed our Universe was flung outwards.

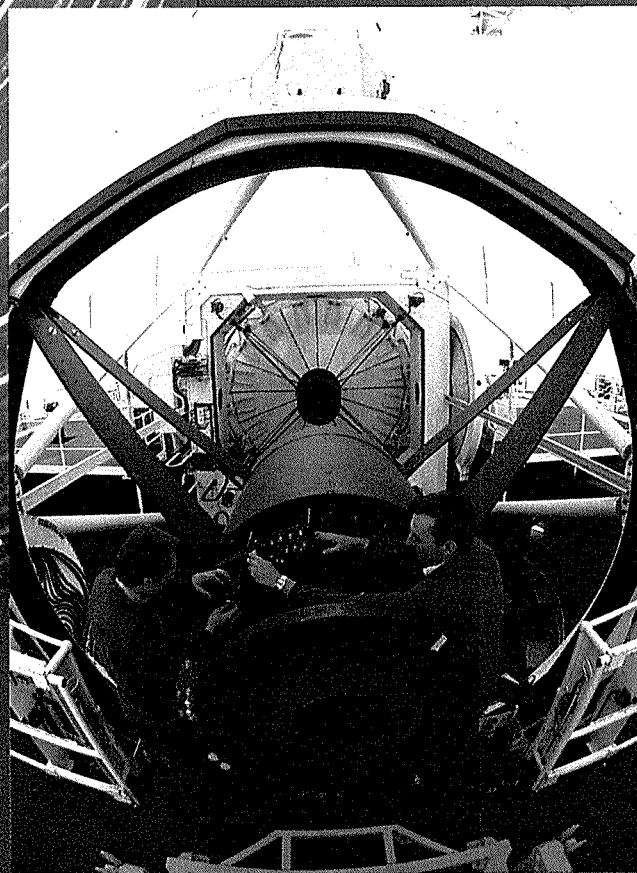
The motion of the heavens is something that has always fascinated humankind. From the earliest times, people saw the stars - and the planets

The William Herschel telescope on La Palma is used to photograph the movement of the heavens. If a camera's shutter is left open, the star's tracks (above) show the Earth's spin.

- moving above them. At first it was thought that the Earth was the centre of the Universe and early scientists came up with complex explanations for the motions of the bodies seen in the night sky. Some seemed to move smoothly around the Earth. Others showed more complex behaviour,

same direction unless pushed.

Second, things accelerate - that is, change speed or direction - at a rate proportional to the size of the force exerted on them. And, third, if two things interact, the force exerted by the first on the second is equal in size and opposite in direction to the force



David Parker/Science Photo Library



exerted on the second by the first. So if you exert a force on a wall by running into it, it exerts an equal and opposite force on you.

Newton also realized that gravity was the force that powered the orbits of the Moon and the planets. The Moon should fall to the Earth – like an apple falling from a tree – under the force of gravity. But that did not mean that it would fall directly to the ground. If its orbital velocity was large enough – which it plainly was – the Moon would fall in a curve.

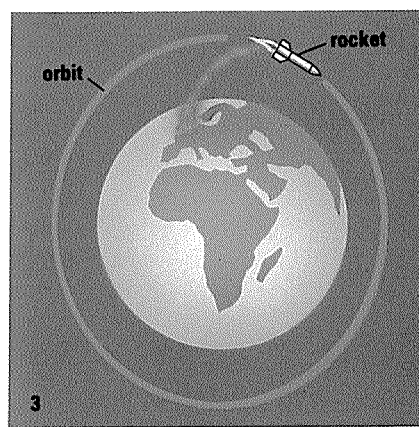
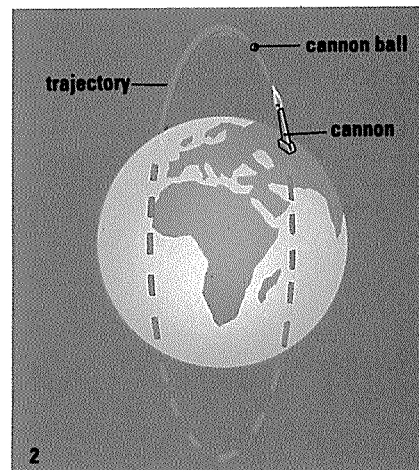
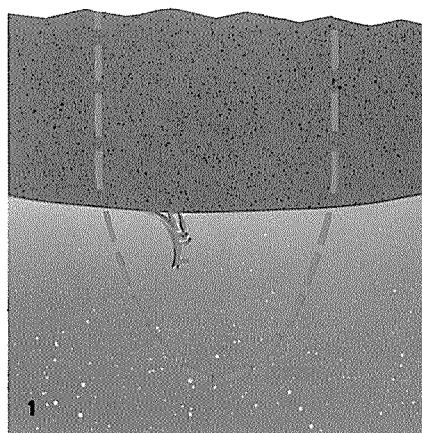
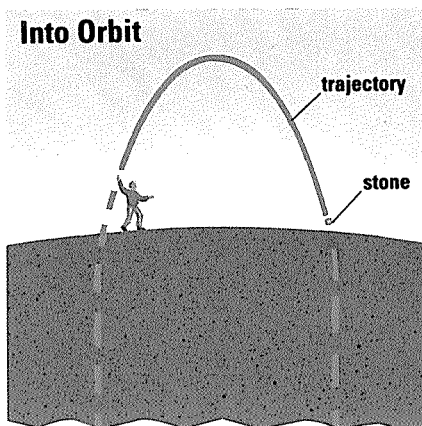
The Moon's fly past

Gravity would act in such a way as to change its direction until it curved right around the Earth in an ellipse. At 384,400 km distance, centre to centre, the Moon was flying past the Earth at some 3,700 km/h.

Likewise the planets were falling into the Sun under its huge gravitational pull. Again, it was their orbital velocity that stopped them smashing directly into the Sun.

To maintain their orbits, the planets

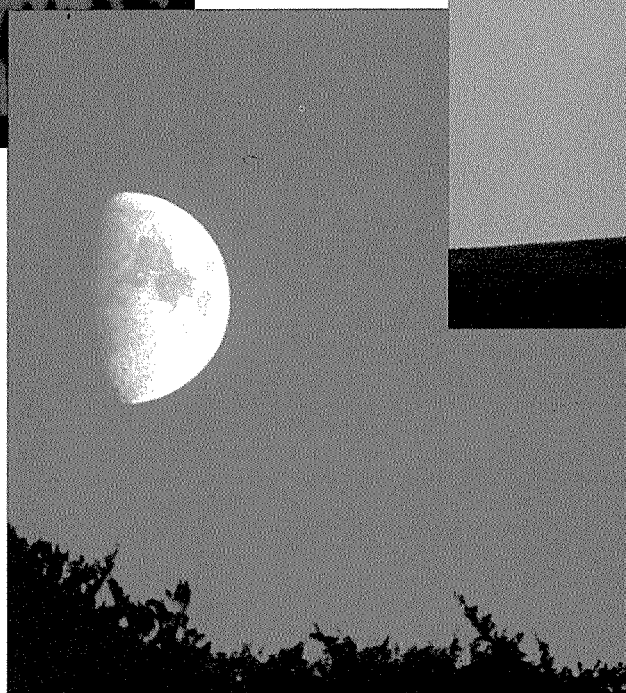
Into Orbit



Even a stone orbits the centre of the Earth (1). If it could pass through the Earth, the orbit would re-appear on the other side. The orbit of a shell (2) also hits the Earth. Only a rocket (3) gives enough speed for an orbit to be maintained.

The Moon is a natural satellite, orbiting the Earth.

Its rotation is exactly synchronized with its orbit, so it always keeps the same side facing us. It appears to change because of the amount it is illuminated by the Sun. The crescent Moon is lit only down one edge. The half Moon (right) is half lit and the full Moon (far right) is fully lit.



all travel at different speeds. Mercury, the planet closest to the Sun, for example, takes just 88 Earth days to travel around its orbit, which is just some 60 million km from the Sun. This means it is travelling at around 180,000 km/h.

The slow planet

Pluto, however, travels much slower. It takes 90,495 Earth days to orbit 5,900 million km from the Sun. That means that it is travelling at just



Spiral galaxies rotate around their bulging centres, leaving long trailing arms. This one is NGC 2997. An end-on view of the spiral galaxy NGC 4565 (below) shows the distinctive central bulge and thinner outer edge of the spinning disc.

are travelling exactly the same speed as Jupiter so there is no danger of a collision. Other minor planets travel in a near circular orbit – like the major planets in the asteroid belt between Mars and Jupiter. Others – like Icarus, Apollo and Aten which actually cross the Earth's orbit – have an orbit that is much more elongated.



Comets' orbits

Even more elongated are the orbits of the comets. But like all the other bodies in the solar system, their regular



Dr. R. Schild, Smithsonian Astrophysical Observatory/SPL

HUBBLE'S CONSTANT

The Universe is expanding and the galaxies are speeding apart at a speed that is proportional to their distance. So if you divide the speed a galaxy is travelling by the distance from it, you should get a number that is the same for all galaxies. That number is called the Hubble Constant, after Edwin Hubble, the man who first discovered this phenomenon. However, no one can quite agree on what this number is. It could be as little as 15 km/s for every million light years. It could be as much 29 km/s per million light years. This would give the Universe an age of between 14 billion and 19 billion years. This is broadly in agreement with other methods that fix the age of the Universe at between 10 and 15 billion years.

Anglo-Australian Telescope Board

17,000 km/h. The Earth proceeds at a stately 100,000 km/h.

Other planets also have moons that move around them. Their motion too is caused by gravity and obeys exactly the same laws of motion. And planets like Saturn and Neptune have

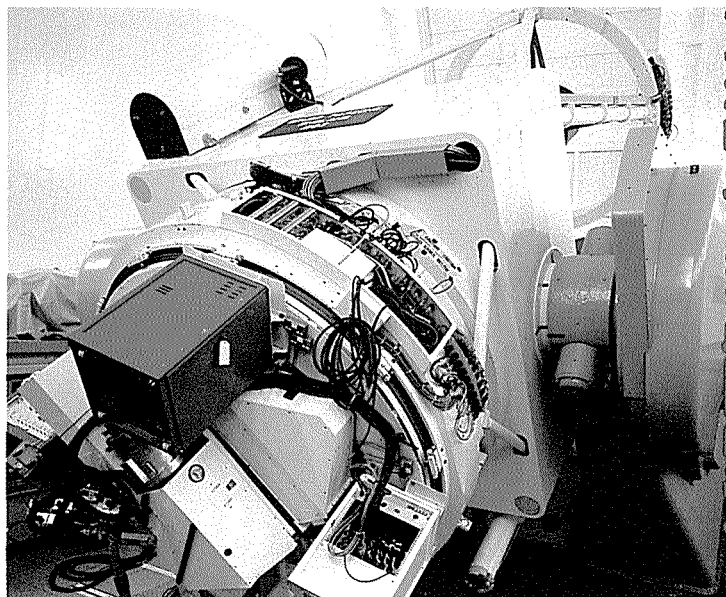
motion is controlled by gravity, though their orbits may take thousands of years.

As well as being in motion around the Sun, the planets and their moons also rotate on their own axes. Some turn at a rate that has nothing to do

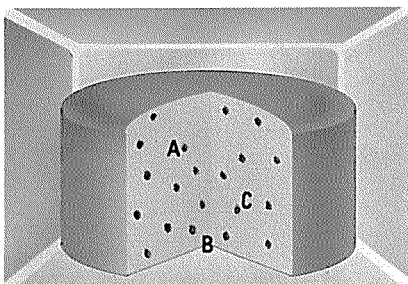
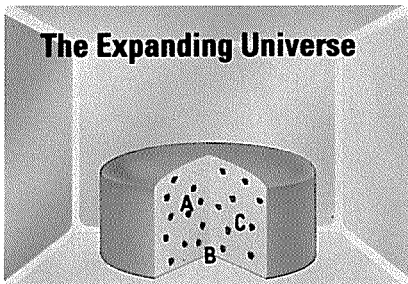
The motion of the heavens is recorded with numerous specialized instruments that cluster around the focus of the Isaac Newton telescope at La Palma in the Canary Islands.

All the galaxies are moving away from us. But we are not at the centre of the Universe. Space is expanding like a cake in an oven. The galaxies are like the currants which all move apart.

Royal Greenwich Observatory/SPL



The Expanding Universe



Mark Franklin

micro-moons, small particles of ice and rock that orbit in huge rings.

Tiny micro planets – or asteroids – also orbit the Sun. Some, the Trojans, travel in the same orbit as Jupiter, but they are about 60 degrees away from it in its orbit. As the diameter of the orbit determines their velocity, they

with their orbit, while others have their spin and orbit locked together. From Earth, only one side of the Moon is ever seen. Its period of rotation is exactly the same as its orbital period.

It is thought that this happens because one side of the Moon is more massive, so the gravitational pull of



the Earth keeps that side Earthwards. But Mercury presents a more puzzling case. It revolves three times on its axis every two orbits – making its day exactly twice as long as its year!

Rotational periods

Most of the bodies that orbit the Sun – from major planets right down to the smallest asteroids – have a rotational period of an Earth day or less. Jupiter,

with its axis of rotation lying practically along the line of its orbit while the other planets stand almost upright with the Sun at its highest along their equator. The Sun itself has a period of rotation of 25 Earth days.

Although the planets all orbit around the Sun, the Sun itself is not stationary. It is a medium-sized star near the end of one of the spiral arms of our galaxy, which is known as the

Comets are balls of ice and dust that have elongated orbits around the Sun. As they near the Sun, gas boils off them. Comet West had two tails. The blue one is gas, the white one dust.

Our solar system is in motion around the centre of our galaxy, the Milky Way. It is a spiral galaxy and we see it end on from one of the outer arms as a broad band of stars. This is the centre of the galaxy that we are travelling around.

THE SOLAR WIND

One of the hidden motions in the solar system is that of the solar wind. It consists of particles of the solar corona – the thin outer atmosphere of the Sun – thrown out into Space at supersonic speeds. As it blows out through the solar system, it picks up evaporated gases from the planets and comets and particles of dust. It blows past the Earth at some 400 km/s and causes the Northern and Southern Lights and magnetic storms that cause radio interference. The solar wind also causes the erosion of the Moon and other bodies in the solar system that are not protected by an atmosphere.

ling towards or away from you, these patterns have their wavelengths 'shifted'. They appear at shorter wavelengths than you would expect if they are travelling towards you, and at longer wavelengths if they are travelling away. This 'Doppler effect' also applies to sound waves and explains why a car horn changes pitch when the car speeds by you.

Big Bang

Not only are the galaxies travelling away from us, but they are travelling at a rate that is directly proportional to

for example, spins on its axis in 9 hours 55 minutes, Saturn in 10 hours 39 minutes.

There are some exceptions, though. Mercury and Venus turn much more slowly because they are slowed by the Sun's huge gravitational pull. Pluto's period of rotation is 6.3 Earth days.

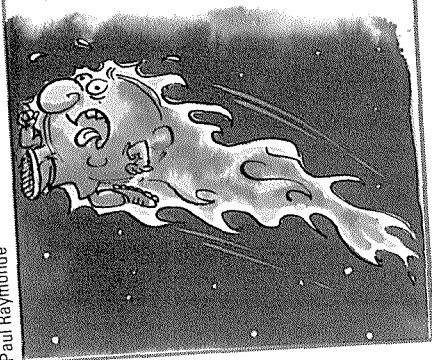
Back spin

However, they do not all spin the same way. While the rest of the solar system spins counter-clockwise, Venus and Uranus spin clockwise. Also, Uranus seems to lie on its side

Just amazing!

TURN, TURN, TURN

THE MILKY WAY IS SO LARGE THAT IT TAKES THE SUN, TRAVELLING AT 100,000 KM/H, ABOUT 200 MILLION YEARS TO COMPLETE ONE ORBIT.



Paul Raymond



Dennis di Cicco/SPL

Milky Way. All the stars in the galaxy orbit around the dense centre of the Milky Way. The entire solar system follows the Sun in its huge orbit around the galaxy's centre.

The 'Doppler effect'

Even the galaxies are in motion. With the exception of a few nearby galaxies, they are all travelling away from us. You can tell just how fast a galaxy is travelling from the light that you receive from it.

Different elements in the stars give off light in distinctive patterns of wavelengths. When they are travel-

their distance – the further away they are the faster they are travelling. This is a very peculiar result because it was first thought to imply that our galaxy was in some way special, at the centre of things.

The only explanation of this that did not give our galaxy some special position in the Universe is that Space itself is expanding and that the galaxies are all moving apart like the currants in a rising cake. This motion originated in the Big Bang, the huge event some 15 billion years ago that began Space, time, the Universe and everything in it.

BOOSTER ROCKETS

EARTH STATIONS

IRIDIUM

CALLS FROM ABOVE

Television signals use ultra high-frequency (UHF) or very high-frequency (VHF) wavebands. These can be beamed into space to be picked up by satellites and rebroadcast around the globe, over distances of thousands of kilometres.

T Horowitz/ZEFA



FLEETS OF SPACECRAFT IN earth orbit are leading to an age of high-speed, planet-wide communications. For every quarter of a century, telephone and television signals have been relayed between various points on the globe using communications satellites. But the latest generation of these spacecraft is opening up remarkable new frontiers.

Communications satellites are launched either by unmanned booster rockets, such as the European Space Agency's Ariane IV, or by the

S Firebaugh/Tony Stone Photo Library, London



Space Shuttle. Most are placed in an almost circular orbit 35,880 kilometres up. At this height, they take exactly 24 hours to travel once around the Earth. As a result, if such a spacecraft is made to orbit directly over the equator, moving west to east, it appears always to hang at the same point in the sky – hence the name ‘geostationary’. In fact, there

Iridium – a worldwide network of 77 low-altitude satellites – will enable owners of portable radio-telephones to make calls to anywhere on Earth.

Shuttle astronauts
Dale Gardner and Joseph Allen retrieve a stranded communications satellite. Allen stands on the end of the remote manipulating arm to receive the satellite as it approaches the Shuttle. Two damaged satellites were retrieved during the mission.



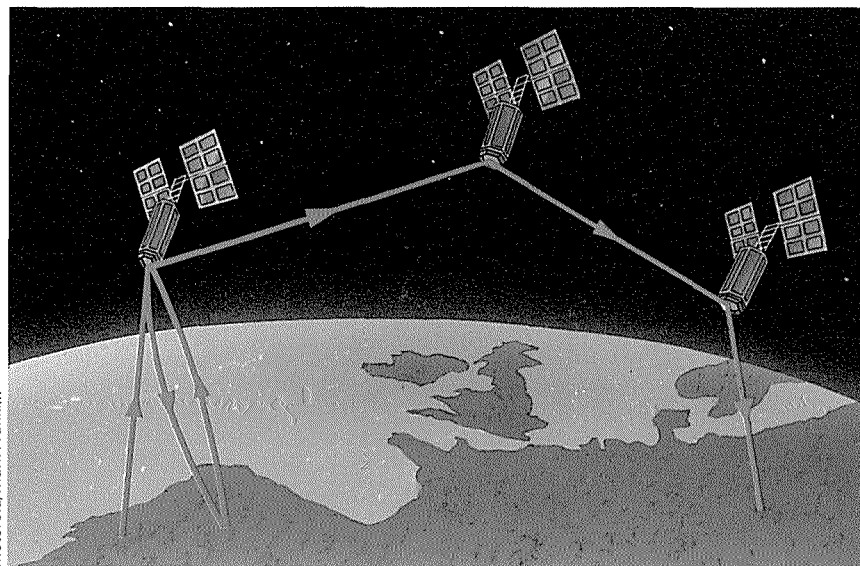
NASA/Science Photo Library

beams the data to a geostationary satellite from where it is rebroadcast. A small aerial on top of the lorry receives the message, which is then reconverted to digital information and displayed on a screen in the cab. A transmitter aboard the lorry automatically flashes its position at regular intervals to a nationwide, radar-based navigational system. In this way, the vehicle can be tracked and its location made known to the satellite.

Remote system

Another planned innovation will allow callers in remote areas to communicate easily by phone. Known as Iridium, it will use a network of 77 small satellites orbiting the Earth 665 kilometres up. At this height, they will be low enough to transmit signals to phones equipped with miniature aerials. A caller will send both his phone number and personal code number from the handset to a ‘smart’ satellite. This will relay the call to another satellite orbiting over the nearest regional service centre.

After the centre checks the information and authorizes the call, the smart satellite will beam the phone message to a third satellite orbiting over the intended party. From here the message will travel directly to the receiver’s handset or into the local phone network via an Earth station.



Motorola/Mark Franklin

are dozens of active communications satellites already orbiting the Earth, with new ones being added almost every month. The most sophisticated of these can carry 30,000 phone calls and several colour TV transmissions simultaneously. In addition, computer

data, navigational information for ships and top-secret military messages can be bounced around the world in this way.

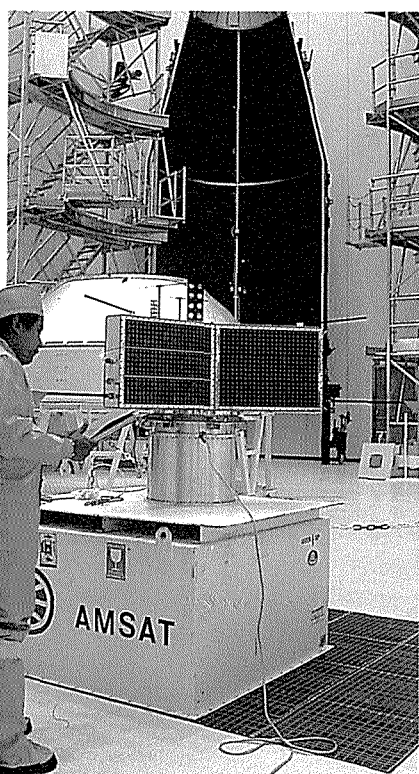
Signals are beamed up to a communications satellite by a large, dish-shaped aerial at an Earth station, in the form of microwaves. These are very short radio waves in the frequency band from 4 to 14 gigahertz. (One gigahertz is a billion cycles per second.)

The upward-travelling waves activate a transponder on the satellite. This causes the satellite to boost the strength of the incoming signal and then retransmit it to a different part of the Earth’s surface, where it is picked up by another aerial.

Lorry link

One of the latest developments in satellite communications allows large, transcontinental lorries and their company headquarters to stay in close touch with each other. A controller sends a computerized message along the phone lines to a special computer centre. There, the digital information is prepared for radio transmission and tagged with an ‘address’ code for the intended vehicle. A dish-aerial

An engineer makes final checks on Oscar, an amateur radio communications satellite that was sent into orbit on board ESA’s Ariane-IV rocket.



Laurent Maous/Gamma/Frank Spooner Pictures

Just amazing!

LONG DISTANCE

THE LONGEST TELEPHONE CALL EVER MADE COVERED A DISTANCE OF 158,845 KM VIA TWO SATELLITES – ONE OVER THE INDIAN OCEAN AND THE OTHER OVER THE PACIFIC.



Paul Raymond

SPACE SICKNESS

BOREDOM

DISORIENTATION

• SENSE OF SPACE

IN SPACE, ASTRONAUTS experience completely different sensations from on Earth – high acceleration at launch followed by weightlessness in an airtight spacecraft surrounded by a silent vacuum.

Not surprisingly, when Space shots first began, doctors wondered whether astronauts would suffer disorientation or sensory deprivation. And they began to wonder if the first astronauts were hallucinating when they reported seeing incredible detail on Earth from orbit, 200 km up – vapour trails of aircraft, ships' wakes and even the smoke from a locomotive. In theory, all these objects should have been too narrow to see. But photographs taken on later missions confirmed the astronauts' stories. Sharp contrasts in colour and brightness made the detail visible.

• Boredom

As it turned out, the first humans in Space had little difficulty adjusting to their new environment. Only on more recent flights, where astronauts and cosmonauts have lived in Space stations for months, have psychological problems such as boredom arisen.

Many astronauts have experienced some initial disorientation, such as a feeling of tumbling or flying upside down on entering orbit, but this soon passes. The main problem has been Space sickness, which is like the travel sickness some people experience on Earth. Two-thirds of astronauts making their first trip aboard the Space Shuttle suffer from some form of Space sickness during their first day or two in orbit.

• Motion sickness

Even now the cause of this affliction is not fully understood, but it involves the body's balancing sensors in the inner ear. On Earth, travel sickness is caused by unfamiliar movement in gravity. In Space, it is the absence of any sense of gravity that leads to sickness, particularly when astronauts turn their heads quickly.

The Earth's surface photographed from a Space Shuttle. Smog, haze and vapour trails can be seen over Atlanta – one of America's major airline hubs.

Without gravity, astronauts in Space might not get the required rest. To rectify this, the new 'sleep restraint' was tested on board Skylab.

Symptoms range from slight queasiness and sweating to repeated vomiting. In most cases, the sickness passes after three or four days, although some astronauts have remained unwell for a week or more. At present, there is no reliable way of

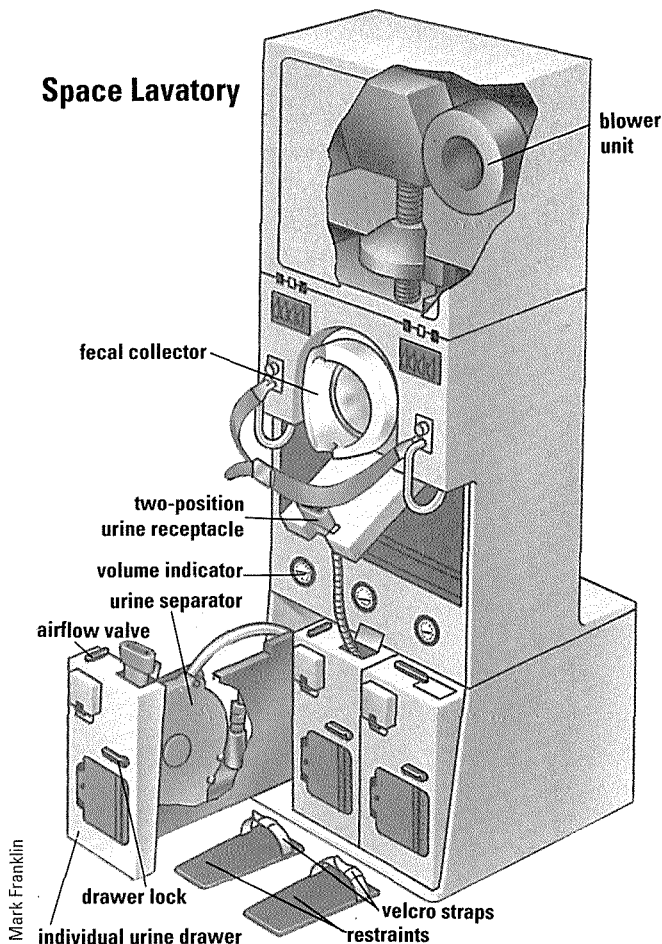


NASA/SPL

NASA



Space Lavatory



Mark Franklin

THE GREAT WALL

Although astronauts can see amazing detail on Earth, one feature they have had difficulty spotting is the Great Wall of China – despite a popular myth that says it is the most prominent man-made object in the world. Astronaut William Pogue, who flew on the US Space station Skylab, said he could see the Wall with binoculars, but not with the naked eye. The Wall does not even show up in photographs from Space. This photograph from a Landsat shows sand piling up against the north side of the Wall, although the Wall itself is not visible.

NASA

Even small creatures such as spiders can adapt to weightlessness – as Skylab's experiment shows.

Human waste management in Space is effected via a collector module. During use, the crew member straps on to the unit, either in a seated or standing position, while his or her body wastes are drawn into fecal or urine collectors through suction. Urine is dumped in Space and faeces dumped back on Earth.

Simple experiments have been done to see how other creatures adjust to weightlessness. Two spiders named Arabella and Anita were taken aboard Skylab. At first, Arabella had difficulty spinning proper webs in weightlessness, but as she adapted the webs improved. Anita, who was allowed to adjust to weightlessness first, spun normal webs when it was her turn. Minnows brought from Earth at first swam in tight loops but others, which were hatched in Skylab, swam normally from birth.

Space bed

Sleeping in Space can be very relaxing but many astronauts have missed the reassuring feeling of a bed and pillow pressing against their body. To rectify this, European Space Agency astronaut Wubbo Ockels de-



NASA

predicting who will suffer Space sickness and who will not. Nor is there any way of preventing it.

In weightless conditions, blood collects in an astronaut's head, making their face appear puffy and giving them a stuffy nose – the effect is similar to that of hanging upside down. This increase of blood in the head may explain changes in the sense of taste in Space. Astronauts have repeatedly called for spicier foods. Aboard the Salyut 6 Space station, for example, Georgi Grechko and Yuri Romanenko used up their three-month supply of spices in five weeks.

Taste meter

Polish scientists tested Salyut crew members with a taste meter that passed a tiny electric current through their tongues to create a sense of taste. In orbit, they found that larger currents were needed to stimulate a reaction in some crew members.

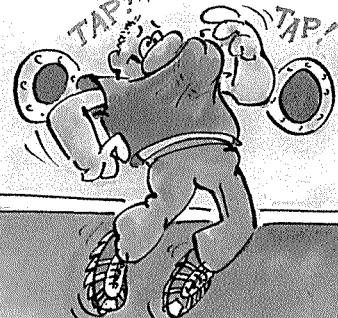
Without gravity, there is no sense of 'up' or 'down'. An astronaut can float freely in any position. Even with their feet on the floor there is no feeling of pressure as on Earth. To help astronauts orient themselves, spacecraft are designed with a clearly defined 'floor' and 'ceiling' and astronauts have found it helpful to remain the right way up with respect to them.

signed a sleeping bag consisting of flameproof fabric stretched over an inflatable tube to hold the sleeper comfortably in place. Ockels tested the device successfully on a Shuttle mission in 1985 and Soviet astronauts used it aboard the Mir Space station. On return to Earth, however, astronauts feel so heavy that even the softest bed can feel uncomfortable.

Just amazing!

HAVE A HEART

ASTRONAUTS EXPERIENCE A TAPPING INSIDE THEIR RIB-CAGE THAT IS IN FACT THEIR OWN HEART, WHICH HAS RISEN WITHIN THEIR CHEST CAVITY DUE TO THE LACK OF GRAVITY.



Paul Raymonde

 KINETIC ENERGY

 SUPERNOVAE

 HII REGIONS

STAR POWER

WHAT MAKES THE STARS shine? What powers the giant radio galaxies and quasars? What is the source of all this energy? Although the Universe is a very big and complex place, there are only a few sources of energy. By far the most important is gravity.

Gravitational energy is released when objects fall towards each other, or when a mass of many particles shrinks under its own weight. In most cases gravitational energy is converted first into kinetic energy (energy of motion as the objects are pulled together), then into heat energy (as they collide and stop) and is finally carried away as electromagnetic energy or radiation.

Many different kinds of objects in the Universe generate energy, some small and some very powerful. Gravity has a role to play in all of them, either as the source of power itself, or else as the key that unlocks other possible sources.

Among the smallest objects are the planets. Although we think of the planets as inert bodies, visible only be-

cause they reflect light from the Sun, they also produce energy of their own. The Earth was originally heated by gravitational contraction, but much of the heat now comes from radioactivity in the crust.

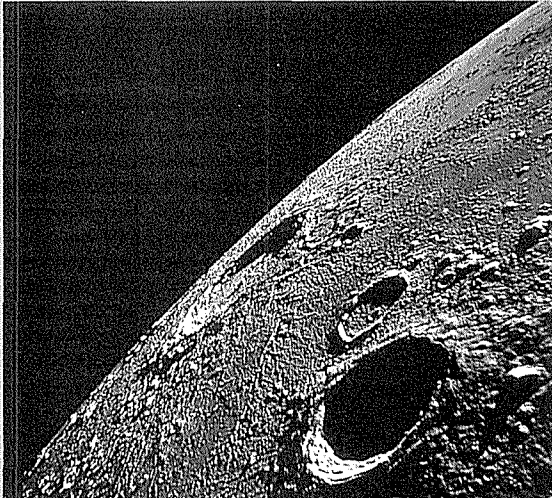
Heat from Jupiter

Jupiter, the largest planet, radiates much more heat than the Earth and about twice as much as it receives from the Sun. Astronomers believe the energy source is entirely gravitational and Jupiter is still shrinking. It may be as hot as 30,000 degrees Celsius in the middle.

When stars condense from clouds of dust and gas they too draw on gravitational energy to heat them-

Star death - the white dwarf is all that remains after a nova explosion in which nuclear power could no longer support the star's weight and its gravity caused a dramatic collapse.

© Hasty Science Photo Library



NASA/SPL **Craters on the Moon** (seen from Apóllo 12) and Earth (right), near Flagstaff, Arizona, USA, are evidence of the power of kinetic energy – the energy carried by moving bodies. As a meteoroid body strikes the surface, a huge explosion occurs.



Hencoup Enterprises/Science Photo Library

selves up. The heat coming from the contracting star warms the dust of the surrounding cloud, radiating infrared waves. Although the star is still invisible, the infrared waves can be detected by astronomers.

New energy

As the temperature rises, the pressure builds up and the contraction slows down. Once the temperature of the core passes 10 million degrees, a new source of energy is unlocked – thermonuclear power. Atoms of hydrogen begin to fuse to form atoms of helium and, in doing so, release nuclear energy. This release of energy

stops the star from contracting further and it shines steadily as a *main sequence star* like the Sun. For many billions of years the power of nuclear fusion keeps gravity at bay.

The most massive stars, when newly born, can be extremely hot, and the radiation from them heats the remains of the dust and gas from which they were born. This gently glowing mass appears as an emission nebula or HII region. All HII regions are powered by new-born stars – their red colour comes from hydrogen.

When the hydrogen fuel starts to run out, the star will go through fur-

THE EARTH'S HEAT

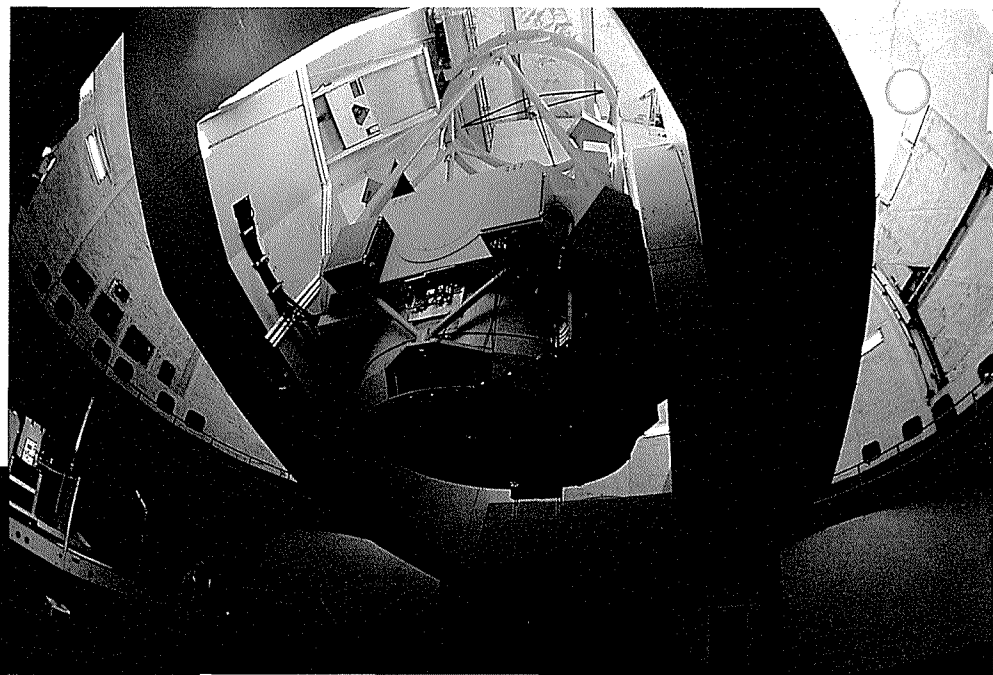
Where does the Earth's heat come from? We know that the Earth condensed out of a cloud of dust and gas over 4.6 billion years ago. Geophysicists estimate that the newly formed Earth originally had a temperature of around 1,000 degrees Celsius.

This heat came from the gravitational energy released by the infalling material. Then the Earth was heated even further by radioactivity from atoms of the elements uranium, thorium and potassium. Today the core of the Earth is believed to be at a temperature of well over 4,000 degrees Celsius.

ther cycles releasing gravitational energy, heating up and burning new fuels until there is nothing left to burn. Gravity finally wins out and the star can no longer support itself against its own weight.

What happens next depends on the mass of the star. A small star like the Sun will collapse into a white dwarf, a compact star made entirely of nuclear ashes. Its atoms are piled on top of each other but can withstand the crushing effect of gravity.

A star several times more massive than the Sun will meet a more violent



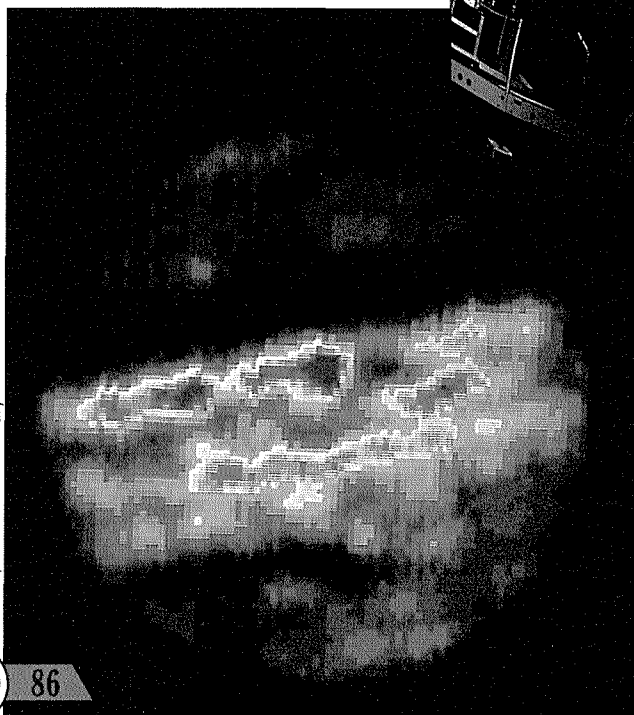
High on a mountain in Hawaii, NASA's **Infrared Telescope Facility (IRTF)** is above most water vapour in Earth's atmosphere which blocks the infrared. Jupiter (IRTF view at left) gives off its own infrared heat. If it were much more massive it would have become a star.

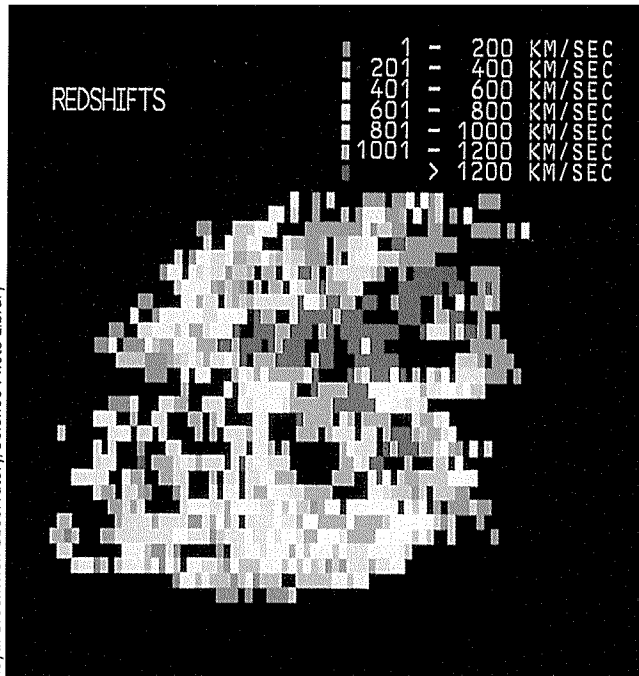
end the instant the fuel runs out. Gravity is so strong that even the atoms themselves are crushed and the core collapses catastrophically. The gravitational energy released is so great that the outer layers of the star are blown into Space in a massive explosion known as a supernova.

The expanding debris from supernova explosions may remain visible for tens of thousands of years. These supernova remnants look rather like the emission nebulae, but they derive their energy from the kinetic energy of the expanding debris as it expands.

F Eschenak/Science Photo Library

NASA/Science Photo Library





Remnant of a supernova
explosion, the Crab Nebula gas cloud is shown here on a map in which the colours reveal different gas velocities.

An image of galaxy M87, located some 50 million light years away, taken with a charge-coupled device camera (inset). M87 may harbour a black hole. The invisible Universe is also probed by huge radio telescopes.

STAR POWER

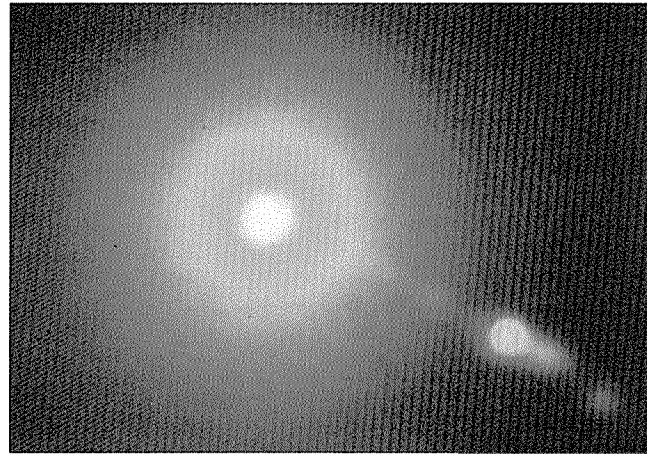
Just amazing!

THE BIG HEAT

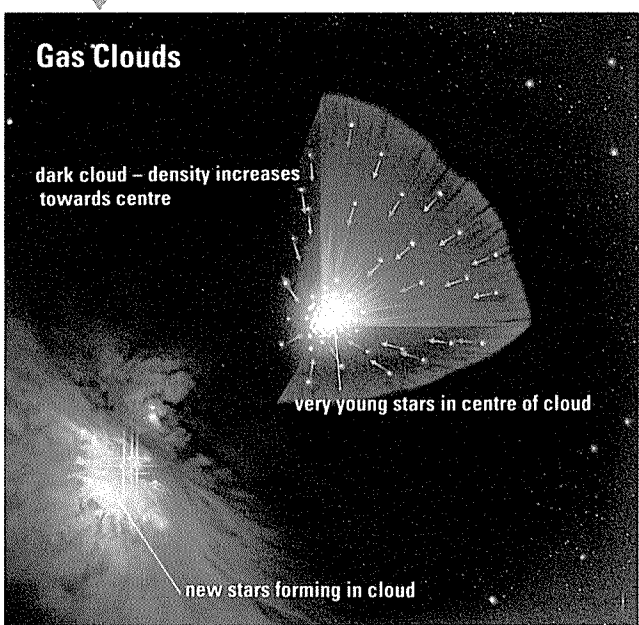
THE EARTH RADIATES ABOUT 30 MILLION MEGAWATTS OF HEAT — EQUAL TO THE ENERGY PRODUCED BY 30,000 LARGE POWER STATIONS.

Paul Raymond

An artist's impression of the Orion Nebula, a giant gas cloud complex which is the most prominent HII region close to Earth. We can only see that part of the outside of the cloud which is lit up by recently formed stars. At its centre, hidden from our view, are many more stars created from the collapse of the gas cloud.

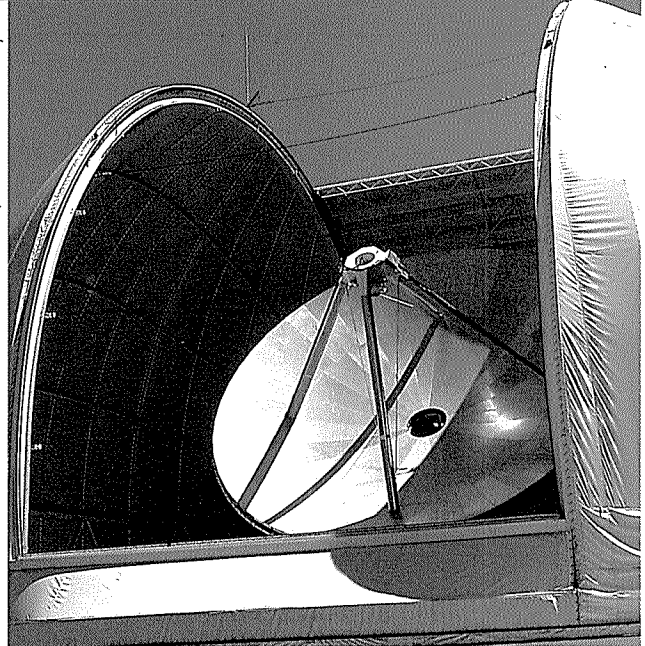


lapsed star is in orbit around an ordinary star it can pull gas off the other star and drag it down like water going down a plug hole. The swirling gas crashes down on to the collapsed star and is heated to very high temperatures at which it gives off X-rays. Most of the X-ray sources in the



Simon Critchley

Dr S Gull/Science Photo Library



D Parker/Science Photo Library

All that is left of the star is a dense ball of neutrons (crushed atoms) known as a neutron star. Neutron stars pack the mass of the Sun into a ball only a few kilometres across. Like white dwarfs they have no internal resources of energy and they too will eventually cool and die.

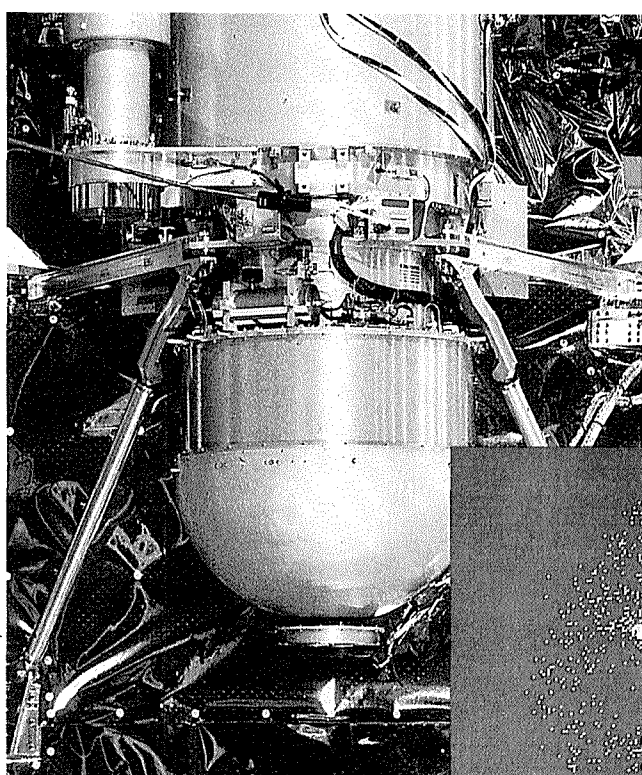
But while white dwarfs and neutron stars have exhausted their nucle-

ar energy supplies and cannot shrink any further, that does not mean that they have no further role to play. There are several ways in which these collapsed stars can still act as energy sources.

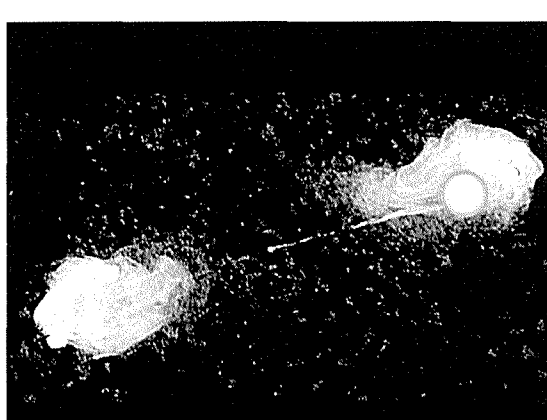
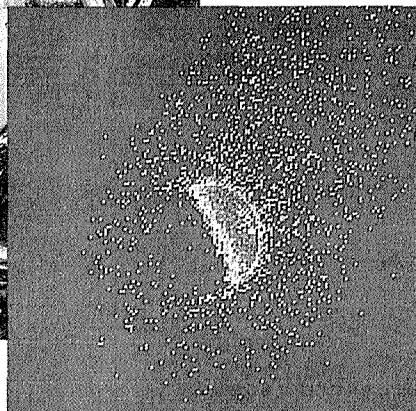
Because they are massive but very small, collapsed stars have very strong gravitational fields into which nearby material can be drawn. If a col-

Galaxy are of this type, as are novae and many other types of variable star. Once again, gravitational energy is being transformed first into kinetic energy, then into heat energy and then finally into radiation.

Neutron stars have yet another way to generate further power. They possess very strong magnetic fields and are rapidly spinning, up to many



The study of X-ray emission in Space is carried out using new X-ray telescopes on satellites such as Rosat. Its X-ray view of the Moon (below) reveals for the first time that it is silhouetted against distant X-ray emitting sources (such as quasars) in the Universe.



A radio 'photograph' of the active galaxy Cygnus A – a powerful emitter of energy at radio wavelengths.

NRAO/AUI/Science Photo Library

star collapsing to a point. It has vanished into a black hole.

A black hole is a region of Space where gravity is so strong that not even light can escape from it. While the hole itself cannot be seen, the effects of its gravity are only too plain.

Mysterious quasars

The most powerful objects in the Universe, the distant and mysterious quasars, are currently believed to be galaxies harbouring massive black holes in the centres. These monstrous black holes, so the theory goes, may have swallowed as many as a billion stars and continue to gobble stars and gas from the surrounding galaxy, wrenching them to pieces in the swirling whirlpool around the hole. The amount of gravitational energy released by matter pouring down the hole can be many thousands of times the normal output of an entire galaxy.

hundreds of times a second. The whirling magnetic field generates a beam of radio waves and as it sweeps round we see pulses just like flashes from a lighthouse – a pulsar.

Neutron stars

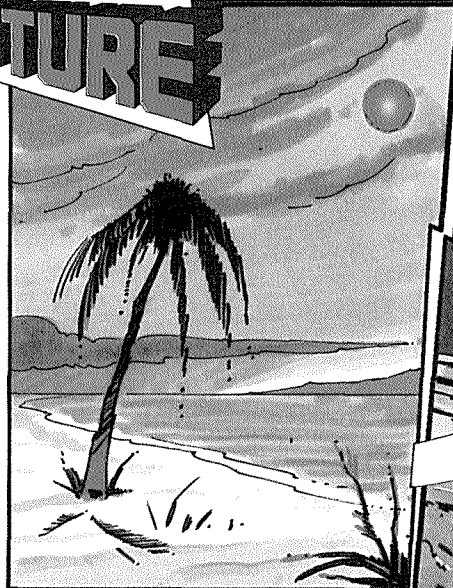
The kinetic energy of rotation is being radiated away as electromagnetic energy and the neutron star gradually slows down and will eventually stop. If the neutron star is young, the magnetic field may accelerate particles which excite the gas of the supernova

remnant. The Crab nebula, a supernova that exploded in 1054, is still being powered by the pulsar within it.

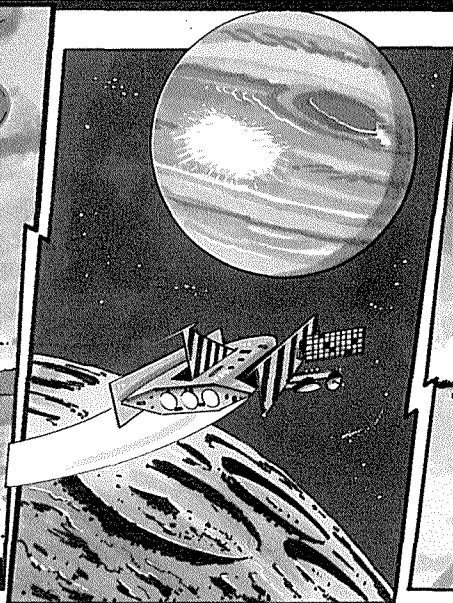
For most stars, white dwarfs and neutron stars are the end of the line. Gravity meets its match and cannot shrink them any further. But if the star is bigger still, its burned-out core does not stop collapsing when it becomes a neutron star. The neutrons themselves are crushed out of existence and there is nothing left to stop the

INTO THE FUTURE

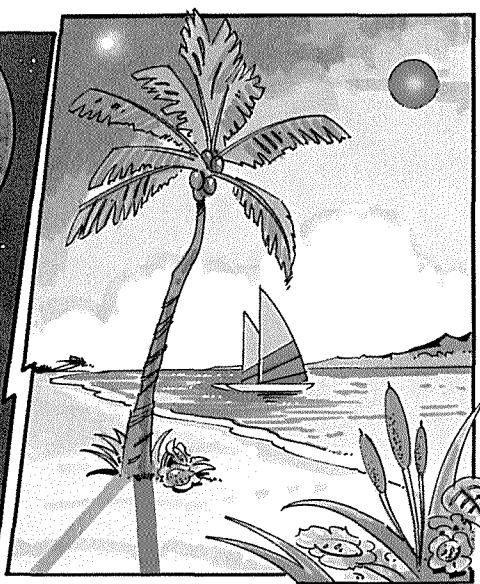
BIRTH OF A SUN



▲ One day, the Sun may lose its power and the world may be in danger of freezing, turning tropical zones of the Earth into vast arctic deserts.



▲ Scientists may turn the giant planet Jupiter into a huge fusion reactor, igniting its reserves of hydrogen. The bright new star will be a source of energy.



▲ As a result, the Earth will bask in the light of two suns – the original one, plus the newly shining Jupiter, making up for the loss of energy.

Joe Lawrence

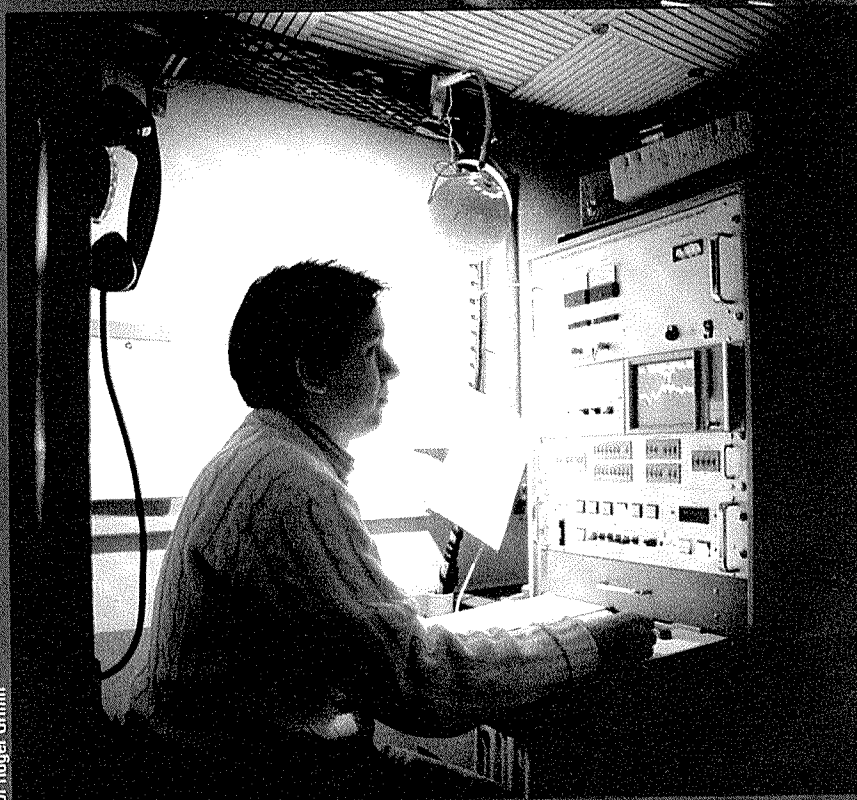
-  STARLIGHT
-  DOPPLER EFFECT
-  SPECTROGRAPHS

SEEING

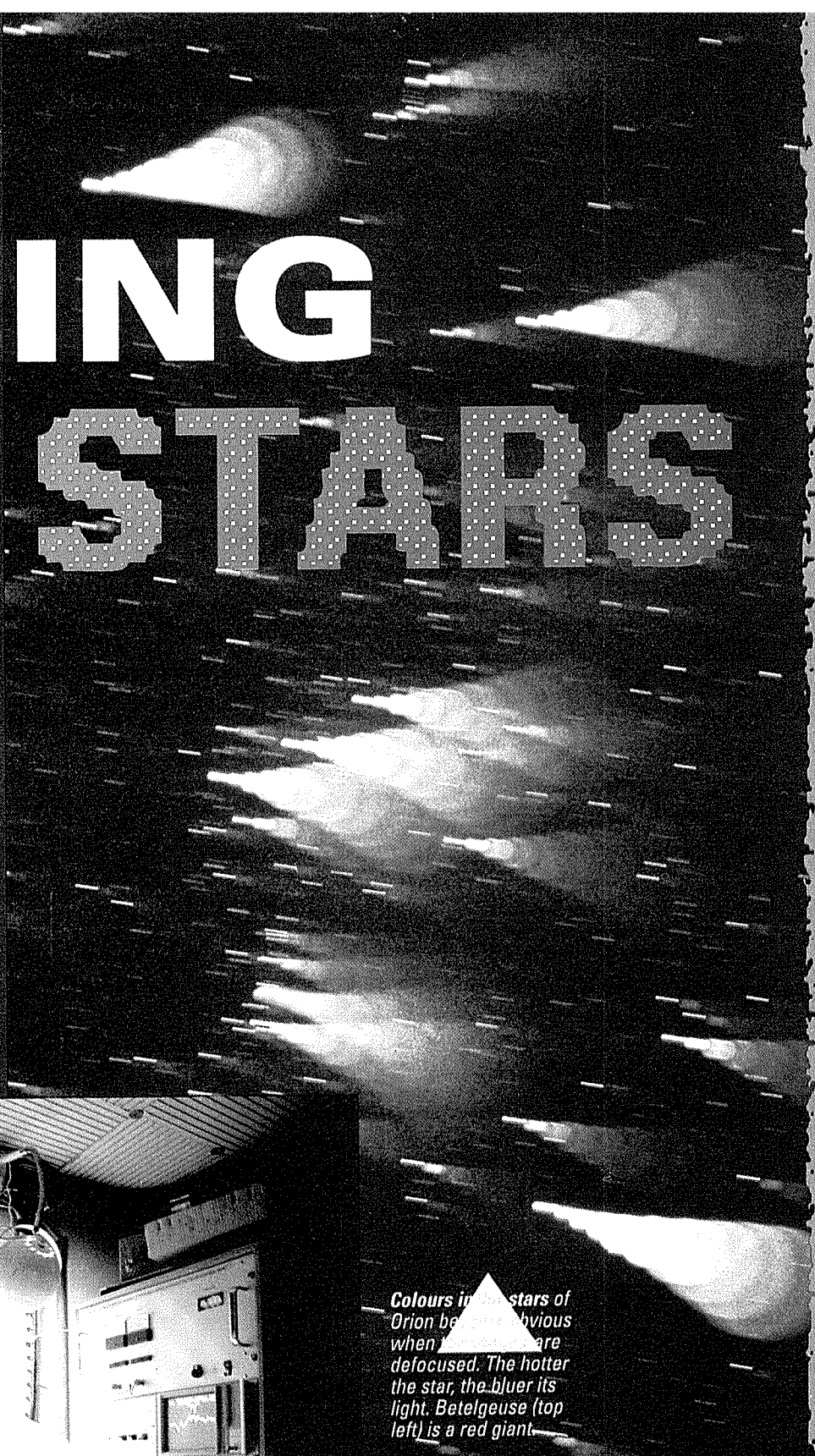
WE KNOW A GREAT DEAL about the stars. We know how hot they are, what they are made of, how fast they are moving, what their masses are, and much else. We also know about the gas lying between the stars, the movements of the galaxies and the age of the Universe. All this knowledge, and much more, comes from studying starlight.

Astronomers can examine the light from a star more closely using a device called a spectrograph or spectrometer. At the heart of the spectrograph is a triangular glass prism that splits or 'disperses' the incoming light into a coloured band called a spectrum. (Instead of a prism, a diffraction grating may be used. This is a piece of glass or metal, ruled with many thousands of narrow lines.) The spectrum (plural, spectra) allows astronomers to see precisely how the starlight is made up.

An astronomer at Haute Provence Observatory, France, measures light from its spectrum, and views a screen in the control room.



Dr. Roger Griffin



Colours in the stars of Orion become obvious when the spectra are defocused. The hotter the star, the bluer its light. Betelgeuse (top left) is a red giant.

When a gas, such as that in a star, is heated it emits light in certain narrow wavelengths. These are called 'lines' because they appear as lines in the spectrum. When a gas is seen in front of a hotter object it absorbs light in the same lines. Patterns of bright or dark lines are seen in the spectra of stars, usually as dark absorption lines from the star's atmosphere. Each chemical element has its own patterns of lines, so a star's spectrum reveals which elements are present.

David Malin/Anglo-Australian Telescope Board

By measuring the lines in the Sun's spectrum, astronomers discovered that it is 73 per cent hydrogen and 25 per cent helium, plus 2 per cent all the other elements. While the spectra of other stars confirm that they are also largely hydrogen and helium, many other elements are present as well.

Star recipe

Astronomers now believe that the first generations of stars were made entirely of hydrogen and helium. The heavier elements were manufactured inside the stars and then blown into Space as they grew old and died. Newer stars, like the Sun, condensed from dust and gas enriched with these heavier elements.

Information about this dust and gas can also be found in starlight. Distant stars appear dimmer and redder



ROE/AATB

Each gas in Space has its own colour – red for hydrogen, green for oxygen. Dust behaves like smoke – it reddens stars beyond, but appears blue when illuminated.

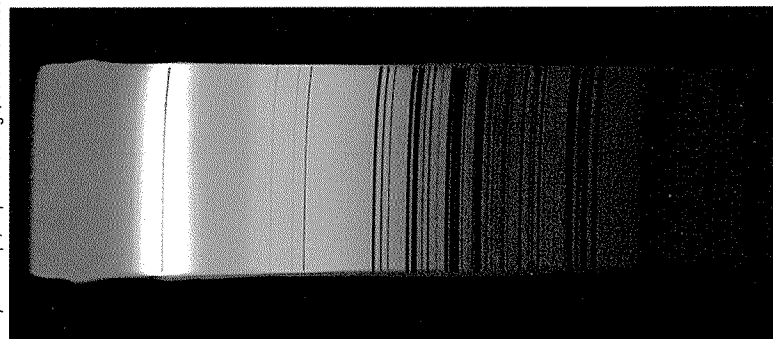
William Herschel Telescope on La Palma, with its spectrograph (red and silver, at bottom). This is used to observe the spectra of very remote objects.

gas is made of similar elements to the gas in the stars.

Apart from chemical composition, spectral lines also tell us about the motion of the star, by the well-known Doppler effect. Light waves from a star coming towards us are compressed and shifted to shorter wavelengths – a blue shift. Those from a star going away are stretched and shifted to longer wavelengths – a red shift. The effect is to move the patterns of lines in the star's spectrum. By measuring the red or blue shift of the lines, astronomers can work out whether a star is moving towards us or away from us and the speed at which it is moving.

The Doppler effect has many uses in astronomy. It can identify two stars

Physics Dept, Imperial College/Science Photo Library



The Sun's spectrum is crossed by dark lines, caused by gases in its outer layers absorbing certain colours, revealing which gases are there.

WHAT ARE REDSHIFTS?

A few astronomers do not believe that the high redshifts of distant galaxies and quasars are caused by Doppler effects and are related to distance. They have pointed to areas of the sky where galaxies and quasars of very different redshift appear to be close together or even connected to each other. If these objects are really nearby in Space, then the redshifts cannot be an accurate measure of distance. Unfortunately it is very difficult to judge whether these connections are real, or caused by a distant object happening to lie almost in the same direction as a nearby object. Most astronomers accept that these are coincidences, and that the redshift is a reliable measure of distance.

than normal, because dust lying along the line of sight absorbs blue light more than red. If we know the distance of the star we can calculate the amount of dust.

Another effect of the dust is to polarize the light from the stars so that it vibrates mainly in one direction. Stars radiate mostly unpolarized light – the waves vibrate equally in all directions. But astronomers have found that in certain parts of the sky starlight is

polarized. This is because the dust grains are not round, but rod-like, and absorb better in one direction than another. The grains must be pointing the same way and astronomers conclude that they are aligned by large-scale magnetic fields in the Galaxy.

Chemical information about interstellar gas also comes from starlight. The spectra of stars show extra lines that come not from their own atmospheres, but from interstellar gas. The

Royal Greenwich Observatory

in close orbit around each other. Although a telescope may show only one star, the spectrograph may reveal a double spectrum, one from each star. Each set of lines is Doppler shifted as the stars move around each other.

If the orbit is edge-on to us, the stars eclipse one another and there is then enough information to work out the masses of the two stars. This is one of the few ways of measuring the masses of stars. In a similar way, it may be possible to detect planets by

aperture door
through which light enters

antenna

solar panels

support systems
module

path of incoming light

Hubble Space Telescope

secondary mirror

inner baffle

fine guidance sensor

central baffle

focal plane
(image formed here)

Paul Williams

2.4 metre primary mirror

boxes containing
scientific instruments

incoming light

entrance aperture assembly

polarizer

diffraction grating

filter

Faint Object Spectrograph
inside one of the instrument boxes

collimators

Digicon light detector

looking at the spectra of suitable stars. A star and a planet will both move around their centre of mass. If the planet is very big, this motion could be detectable in the shifts of the spectral lines of the star, even though the planet is too faint and too near the star to be seen.

Spinning stars

Doppler shifts can also be used to measure the rate of rotation of a star. If a star is spinning, light from one side of it will be redshifted and from the other side blueshifted. The effect is to broaden the spectral lines.

Whole galaxies also have spectra. These are simply blends of the spectra from the stars and gas within them. By looking at the spectrum at various points in a galaxy, astronomers can measure how fast it is rotating. From this they can estimate

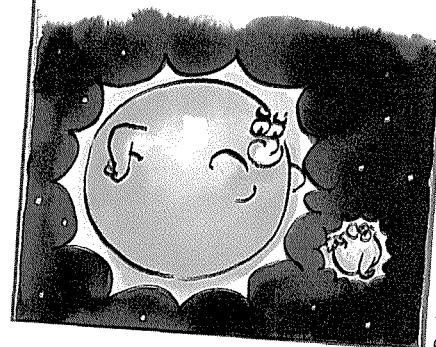
The Hubble Space Telescope (top) focuses light from stars and reflects it to a central focus. The spectrograph (above) uses a diffraction grating to analyse the light.

This quasar seems linked to the galaxy above it. But they have very different redshifts, a puzzle to astronomers.

Just amazing!

MEGASTAR

THE STAR BETELGEUSE, IN THE ORION CONSTELLATION, MEASURES 1,000 MILLION KM ACROSS – 730 TIMES THE DIAMETER OF THE SUN.



Paul Raymond

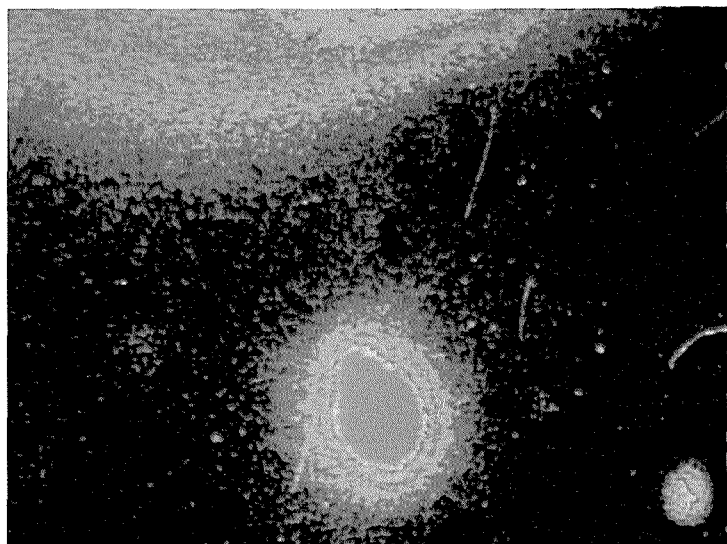
the mass of the galaxy. Galaxies have masses from millions up to tens of thousands of billions of times the mass of the Sun.

Astronomers can study the motions of galaxies in the same way as they study stars. They have discovered that the farther away a galaxy is, the greater redshift it has. So by measuring the redshift of a distant galaxy astronomers can work out both its speed and distance. All the farthest galaxies are moving away from us, and this general expansion is evidence that the Universe began in an explosive Big Bang. From the present rate of expansion, astronomers estimate that the Universe is about 15 billion years old.

High energy quasars

The most distant objects that we can see are quasars – extra-galactic high energy sources. They have enormous redshifts, so large that at first astronomers could not recognize the lines in their spectra. The wavelength of light from them can be over five times as long as normal, which means that these quasars are moving away at almost the speed of light.

S Wyckoff & P Wehinger/Science Photo Library



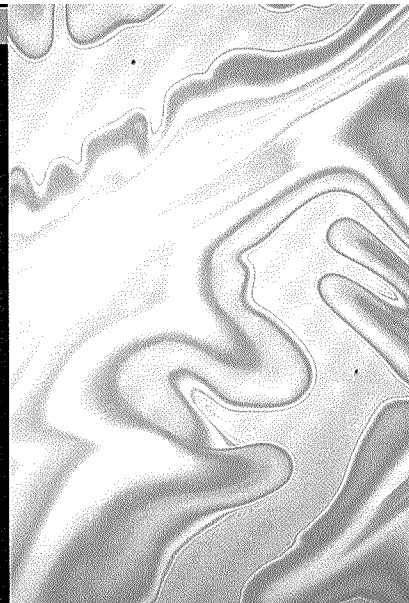
Tony Stone Photo Library, London



A rainbow forms when a low sun shines on drops of rain. These act as prisms, splitting light into colours.

Kanicki/Transglobe/Jerrican

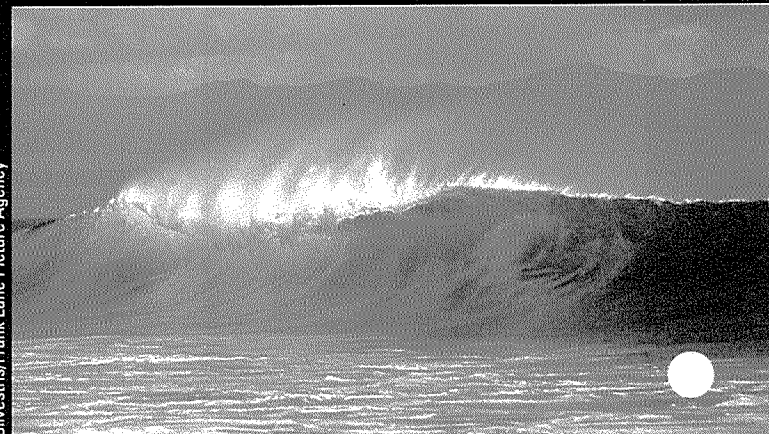
Oil on water shows colour because the thickness of the layer is close to the wavelength of light.



P. Aprehman/Science Photo Library

'Neon' tubes contain neon or argon gas, which glows when current passes through it.

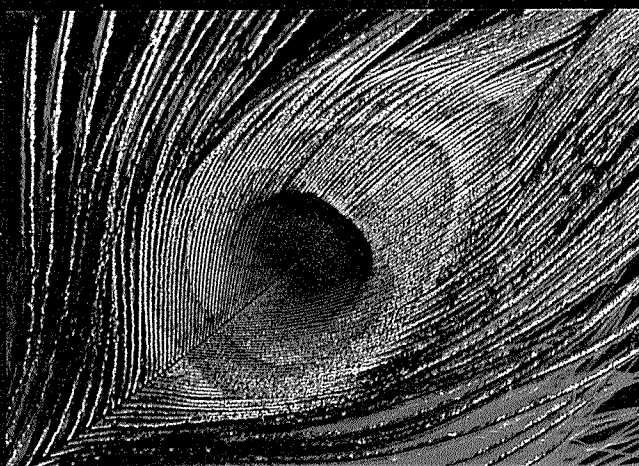
Kanicki/Transglobe/Jerrican



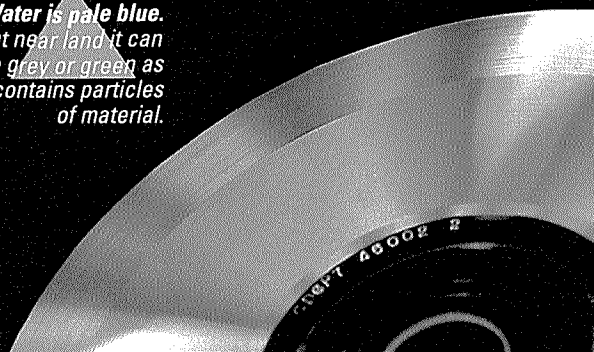
Water is pale blue. But near land it can be grey or green as it contains particles of material.

Silvestris/Frank Lane Picture Agency

Tony Stone Photo Library, London



Peacock feathers show colours by diffraction – like the colours on a CD or record.



D. Armand/Tony Stone Photo Library, London

C. Bell/Tony Stone Photo Library, London



Coal glows red when warm, then yellow and white as it gets hotter. Stars show the same colours at these temperatures.

Phil Jude/Science Photo Library



A CD is coloured by diffraction – when light waves reflected by the grooved surface reinforce or cancel depending on their colour.

Sunset colours are caused when the blue part of the Sun's light is absorbed by layers of air, leaving only the yellow and red wavelengths.



INTERSTELLAR TRAVEL • SPACE PROBES

PHOTON DRIVE

REACH FOR THE STARS

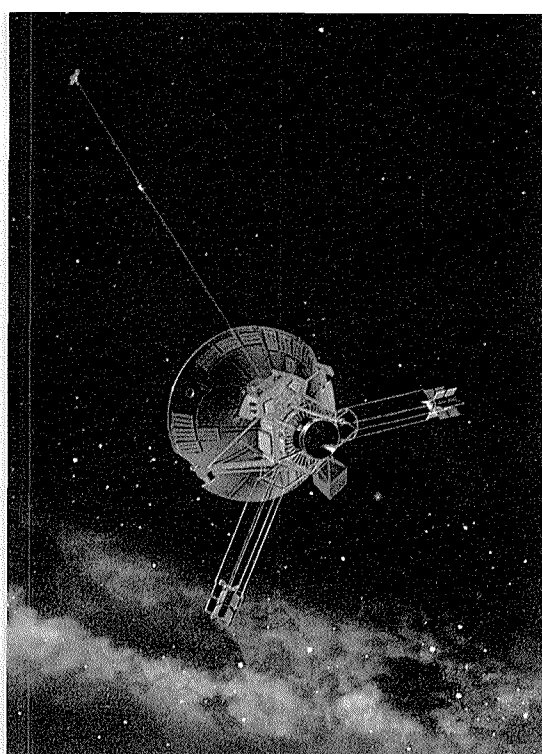
EARTH'S FIRST FOUR

interstellar probes have left the Solar System and are on their way to the stars. Pioneer 10 is now heading towards the constellation Taurus at 40,000 km/h. Also on their way out into interstellar space are Pioneer 11 and Voyagers 1 and 2.

But, even travelling faster than any other manmade object, they will take hundreds of thousands of years to reach other stars. In fact, the first 'close' encounter will be in 300,000 years when Voyager 2 passes within one light year of Sirius.

If mankind wants to go to the stars, scientists will have to find a faster way. The chemical rockets that propelled the Pioneer and Voyager probes used Jupiter's gravity to give them the velocity to escape the Sun's gravitational pull. But their final speeds are 16 km per second. This is

A spaceship lifts off from a moon in another star system. Man has dreamed of travelling beyond our Solar System ever since he realized that it was not unique.



NASA

Pioneer 10 is the first spacecraft to travel into deep Space. The bright star just below the probe's lower boom is Alpha Centauri, the star closest to our Sun.

adequate for travelling within our Solar System, but these techniques cannot give the much greater speeds needed for effective interstellar travel. The main problem is the enormous amount of fuel that has to be carried to keep up the acceleration.

Daedalus Project

Scientists from the British Interplanetary Society made a study to see if there was any way that interstellar travel could be achieved within a century. Their report outlined the Daedalus Project, a planned probe that could reach a nearby star, Barnard's Star, in just 50 years.

The Daedalus probe would be powered by thermonuclear explosions, triggered by the laser compression of deuterium and helium-3 pellets. It would reach a speed of one-tenth the speed of light. The exploding helium pellets would have to be shielded from the rest of the craft and the thermonuclear blast directed out of the back.

Antimatter drive

This form of propulsion would require tremendous engineering advances. Just obtaining enough fuel would require massive collecting operations in the atmosphere of Jupiter, because there is not enough helium-3 on Earth.

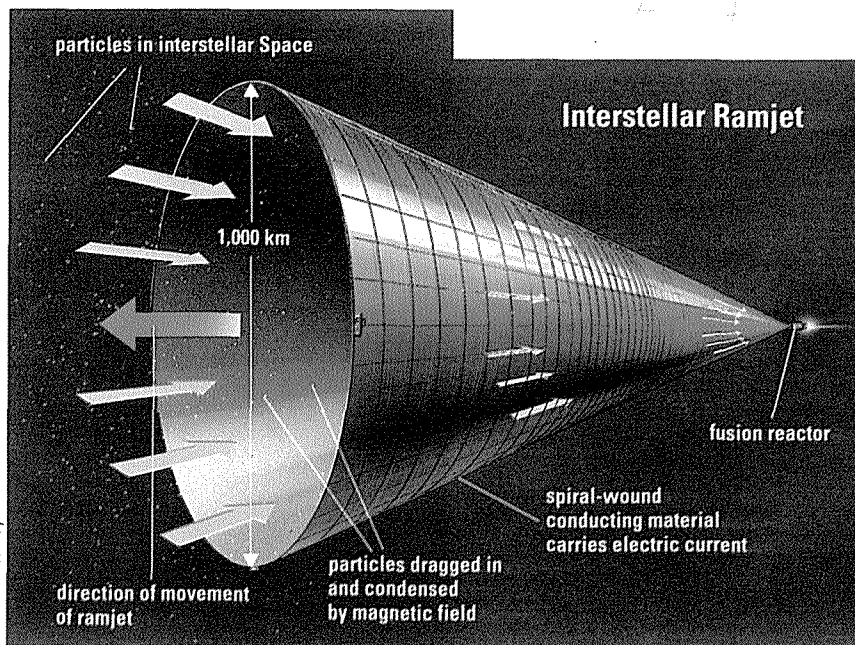
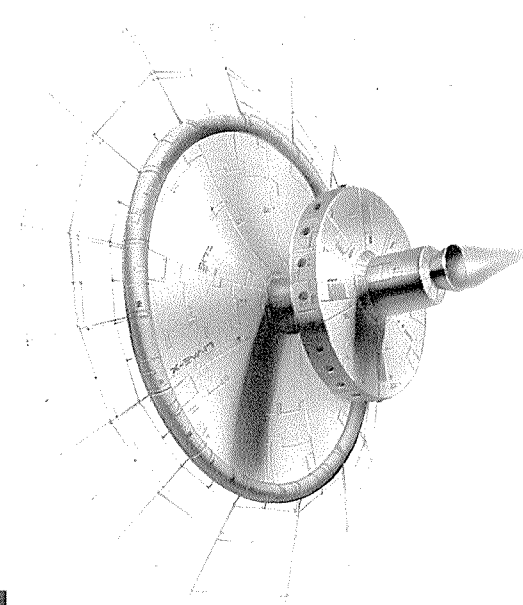
Daedalus would not be powerful enough to carry the supplies needed to support human life for the 50-year journey or the fuel needed to get back home. Manned spacecraft will need another source of propulsion.

Antimatter drive is being studied by scientists in the USA. It is the most

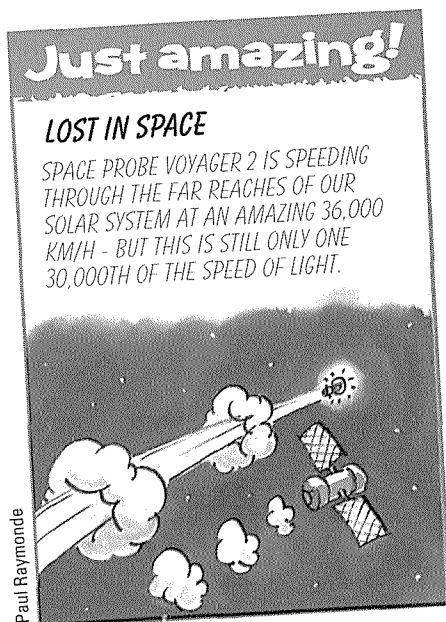
enormous explosion, it would have to be stored in a special way – perhaps in a 'magnetic' bottle. If there was a power failure and the magnetic field went off, the antimatter would come into contact with the matter structure of the craft – and the gamma rays would start to fly. However, less than one per cent of the mass of a spacecraft would need to be antimatter.

The best way of powering an anti-

A fusion ramjet would gather its fuel from Space. The propulsion unit (right) is fuelled by particles ahead of the craft that are gathered together until dense enough for nuclear fusion reactions to take place.



Adrian Chesterman



plausible option for reaching speeds of a few tenths the speed of light. Producing energy by the mutual annihilation of matter and antimatter is the most efficient way we know.

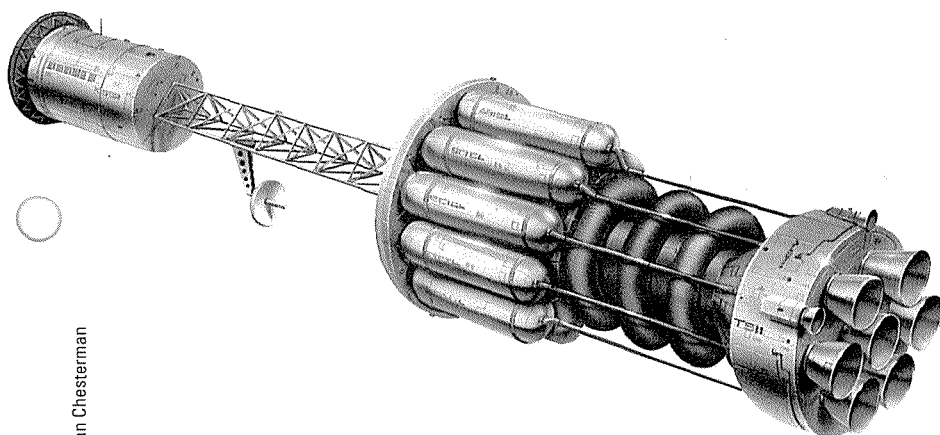
The difficulties lie in producing and storing sufficiently large quantities of antimatter. Until now it has only been made in subatomic amounts. And since antimatter annihilates on contact with matter, producing an

The Andromeda Galaxy, the closest major galaxy to our own, would take over two million years to reach even at speeds approaching that of light.



NASA/Science Photo





Adrian Chesterman

on the concept of a light sail. The particles of light – or photons – are produced not by the spacecraft but by some external source, and are caught by the spacecraft's sail.

Light sails

Some satellites already use the light sailing technique to capture sunlight to turn around. But the light from a star, such as the Sun, is too diffuse to accelerate an interstellar spaceship.

One proposal is to construct huge lasers that could direct enormous power in a very tight beam at a craft

BLACK HOLE TRAVEL

The most far-fetched idea ever proposed for interstellar travel involves black holes, regions with gravitational fields so intense that nothing can escape from them. Mathematicians speculate that there are an infinite number of parallel universes. There may be paths at the centre of rotating black holes that lead from one universe to another. A traveller following such a 'wormhole' would emerge in another spacetime, which could even be a different part of our own universe at some point in the past or future.

matter rocket might be to use a small amount of antimatter to heat a much larger amount of gas. The hot gas would then be expelled out of a rocket nozzle and push the craft forward.

The Daedalus Project and antimatter drive involve the ejection of material to gain momentum. Light also carries momentum, so how

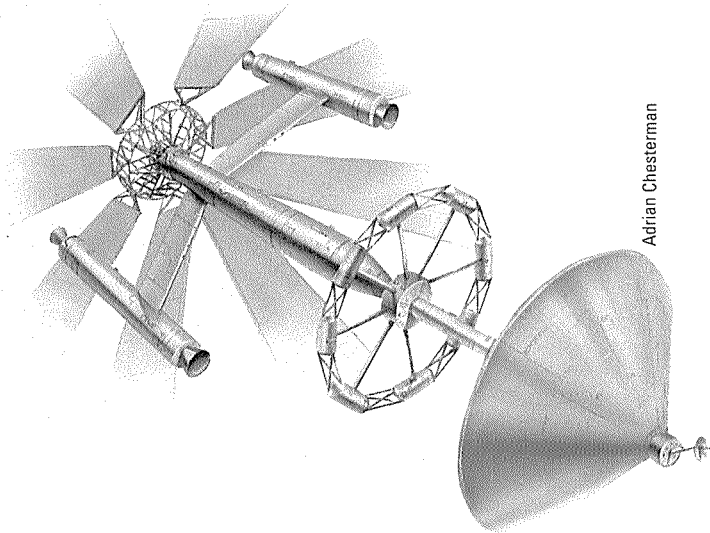
An antimatter drive
would use the energy produced when antimatter meets matter. The antimatter is combined with hydrogen in a combustion chamber.

A spacecraft powered by light.
The theory is that the sails catch light from an external source and the force of this 'light wind' pushes the craft along.

about a rocket powered by light? However, it has become clear that shining a bright light out of one end of a rocket would never produce enough force to propel it along, as in a conventional rocket arrangement.

More recently, interest has centred

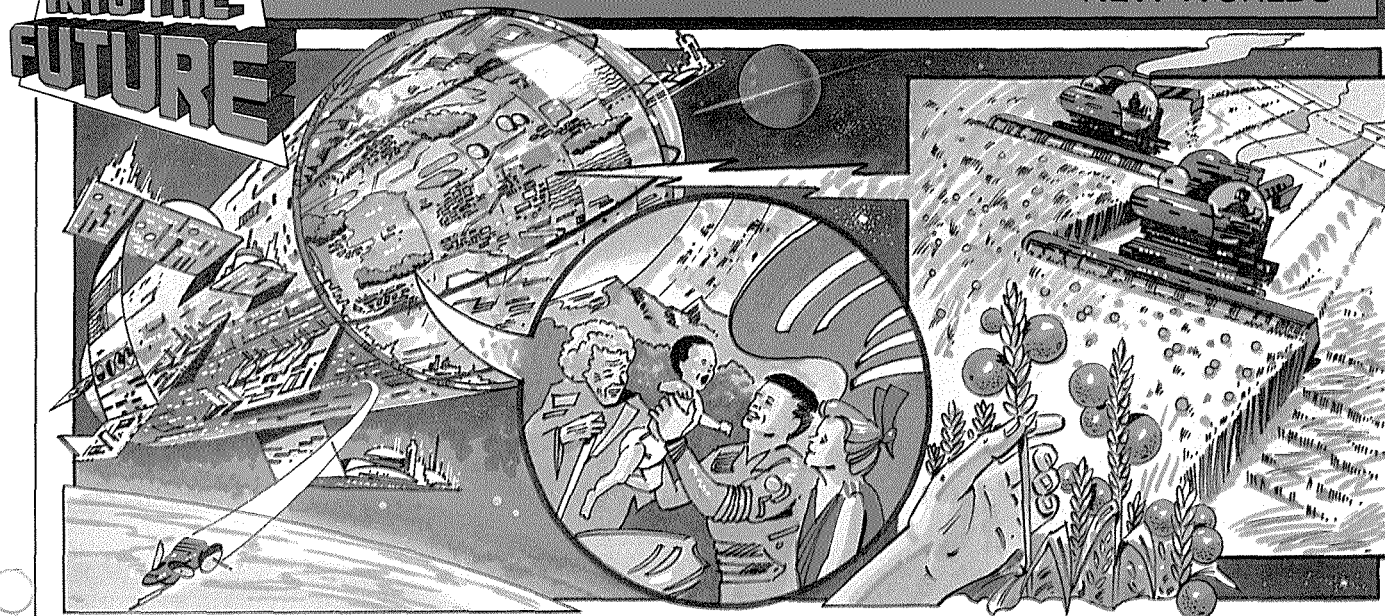
carrying a reflecting sail many kilometres across. However, a billion megawatts would be needed to give a 1,000 tonne spacecraft a reasonable interstellar flight time. This is more than the total world power output at present.



Adrian Chesterman

INTO THE FUTURE

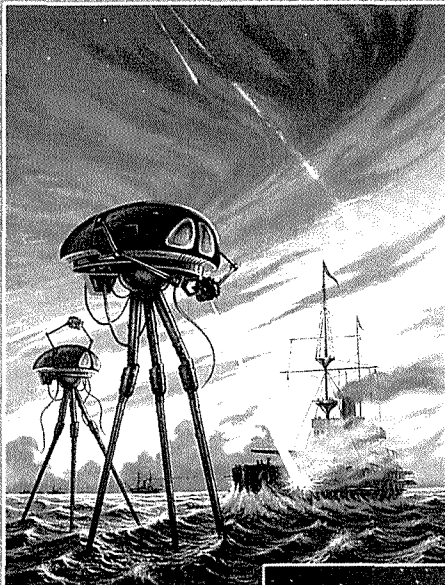
NEW WORLDS



▲ Man may solve the problem of overpopulation on Earth by sending colonists outside our Solar System in search of a habitable planet.

▲ Many generations will live and die on the ships. It has been calculated that it would take tens of millions of years to reach the outer edges of our Galaxy.

▲ A ship would have to be completely self-sufficient. It might become the permanent home of the colony – a friendlier environment than any planet found.



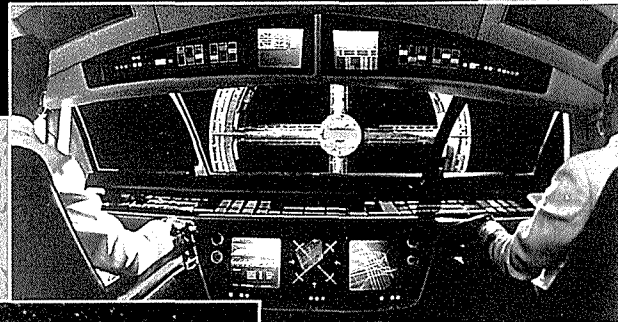
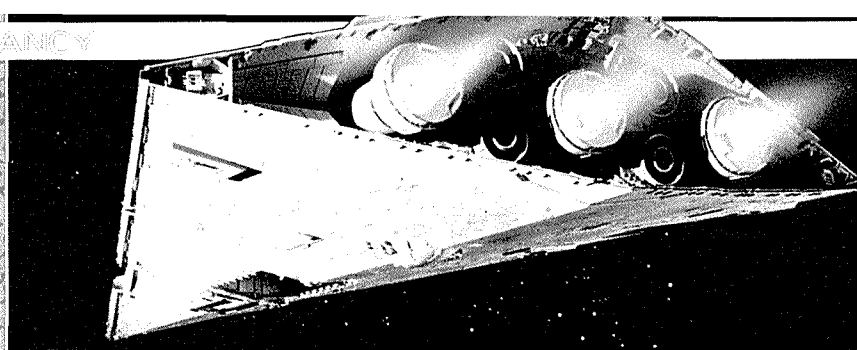
Devon Hardy/Solent Photo Library

Martian flying machines are a staple of the War of the Worlds, written by H.G. Wells in 1898.

The alien Mother Ship, almost half a kilometre across, lands on Devil's Tower in Wyoming, USA, in Close Encounters of the Third Kind.

Starships burn across the Galaxy in Star Wars, as the Rebel forces and evil ruler take on tight control of the Galactic Empire.

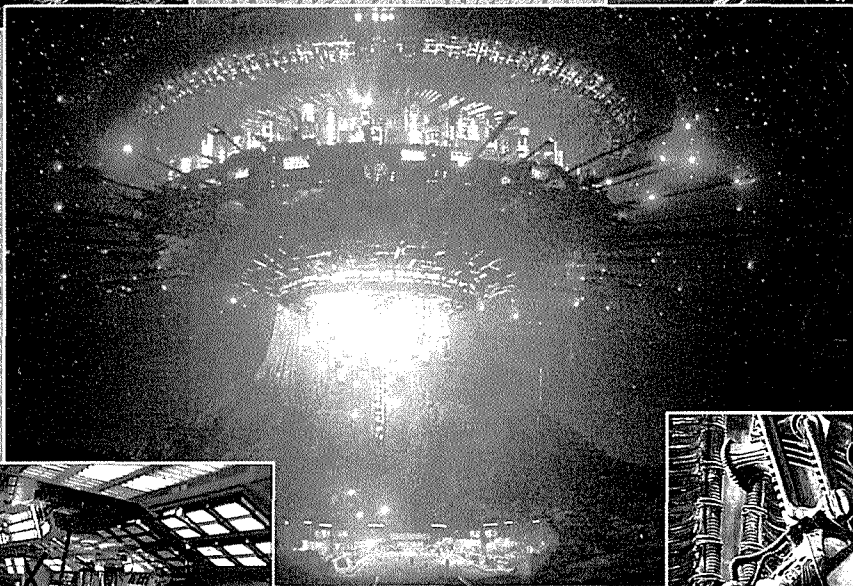
Bored Brain Archive



Spaceship Discovery, in 2001, heads for Saturn, with a high speed of the Moon, to send signals in outer space.

The crew of Space Shuttle Challenger, in 1983, exchange the first of a series of signals with the ground station.

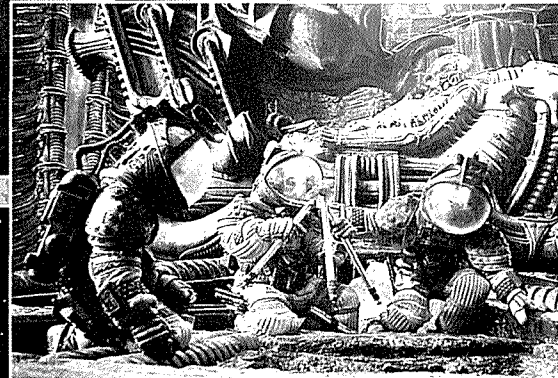
Robert Gault Archive



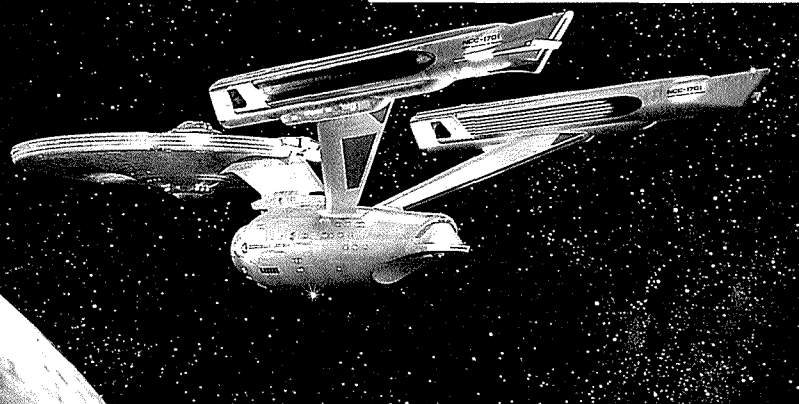
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In 2010, the Russian space craft Leonov, launched in 1968, was launched in 1968, and spent three years before being launched in 1968.

Universal Pictures/Conrad Collection



Universal Pictures/Conrad Collection

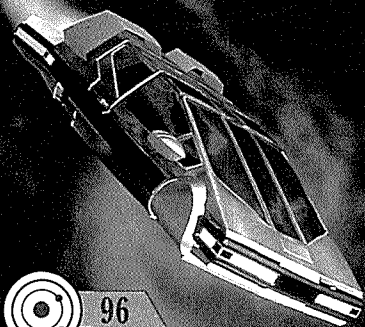


Universal Pictures/Conrad Collection

In the movie, the last Star Wars models were released in 1977, and the first Star Wars models were released in 1977.

Star Wars is the most popular movie in the world, and the first Star Wars movie was released in 1977.

Universal Pictures/Conrad Collection



 DUST CLOUDS

 ASTEROIDS

 RED GIANTS



HOW WILL LIFE ON EARTH END?
Short of destroying ourselves with nuclear war, pollution or forcing climatic change, how long can humankind expect to live? In particular, is there any danger of an astronomical catastrophe outside our control?

Science fiction stories and films are

full of such disasters, some of them plausible, some of them not.

Among the implausible ones are claims that the orbit of the Earth could go terribly wrong and we would be pulled into the Sun. The Earth's orbit is actually very stable and has been for billions of years. The only way it could be changed is by some other planet wandering by and deflecting the path

of the Earth by its gravitational pull. But the other eight planets are also in very stable orbits, and we know of no other object that could come near us – we would have seen it by now! We can be confident that the Earth will stay where it is. For similar reasons we can reject fears that the Earth's axis might 'tip over', causing a terrible change of climate.

But there are wandering objects in the solar system – the meteoroids, asteroids and comets – and some of them do come near the orbit of the Earth from time to time. Most of these are far too small to do serious damage to the Earth itself, but the larger ones would certainly be a threat to the life upon it.

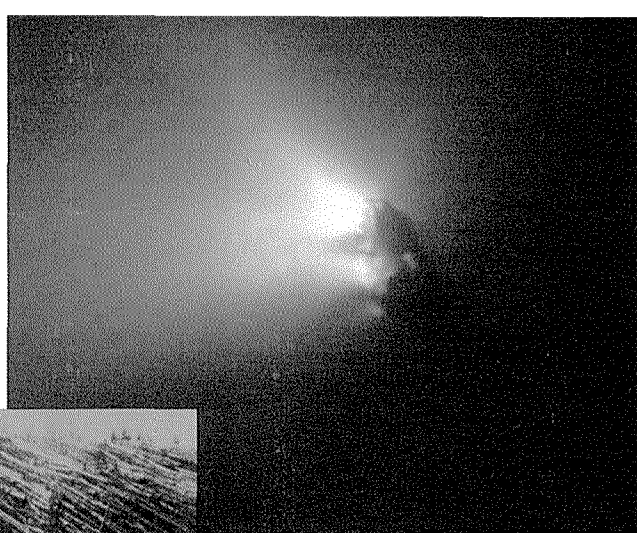
In 1937, and again in 1989, stray

A red giant star hangs like a threat over a desert landscape – a gloomy vision of our own planet's future. The extreme heat of the growing Sun will end all life on Earth.

rocky bodies skimmed past Earth at about twice the distance of the Moon. And on 18 January 1991 an object dashed past at just half the distance of the Moon. Though only 9 metres across, it could have destroyed a small city had the Earth been at a slightly different position in its orbit.

Could there have been a major collision in the past? About 65 million years ago the dinosaurs disappeared, along with more than half of all species of life. No-one knows what happened, but some scientists say there is evidence that the Earth was

Halley's Comet approaches the Sun every 76 years. At its heart is its icy nucleus, only about 10 km across, which was photographed by the spacecraft Giotto in 1986. Gas and dust from the nucleus forms a spectacular tail. A comet hitting the Earth could cause great devastation.



ESA



Trees were flattened over a large area of Siberia following a mysterious explosion in 1908. No traces of a meteorite were found, but scientists now believe that a small comet hit the Earth.

hit by an asteroid or comet about the same time as the dinosaurs vanished.

The dust from the explosion would have plunged the whole world into darkness for many months or years. If the object landed in the sea the water vapour boiled out of the ocean would lead to a strong greenhouse effect and extreme heat. If it landed in a limestone region, vast quantities of carbon dioxide would be released, also causing a greenhouse effect. Nitrogen in the air would be burned and nitric acid would rain from the skies.

Nemesis

But why should such a large asteroid or comet suddenly fall on the Earth? Some scientists argue that the Sun



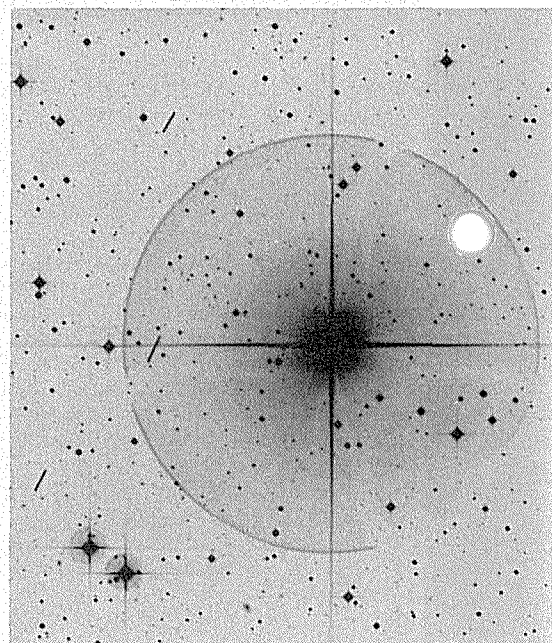
Michael Carroll/Space Art International

ON A COLLISION COURSE WITH EARTH

Of all the possible disasters facing our Earth, the impact of a large asteroid or comet is the only one to cause us any concern. What warning would we have of such a collision?

Most asteroids lie between the orbits of Mars and Jupiter, out of harm's way. But some asteroids have orbits which bring them closer to Earth. Because they are small and have no light of their own, they are usually very faint until they come into the inner solar system and are lit up by the Sun.

Nonetheless, new asteroids are being found all the time on very sensitive photographic surveys. Moving around the Sun, they appear as moving points of light, leaving behind trails on long-exposure photographs (right). Astronomers can predict the paths of the larger objects for years ahead. But an unknown object (less than 1 km across) could appear with very little warning. And even if we knew it was coming, there is probably little we could do about it.



An artist's impression of how a falling meteorite might affect a large inhabited area – Manhattan – leaving behind a huge crater.

Could the solar system be destroyed by collision with a star? There are about two hundred billion stars in the Galaxy, all rushing around at many kilometres a second. In the first half of this century astronomers used to think that the solar system was created by a near-collision of the Sun and a wandering star. The star's gravitational pull dragged a stream of gas out of the Sun, which then condensed to form Earth and the other planets. That theory was rejected when astronomers realized that such

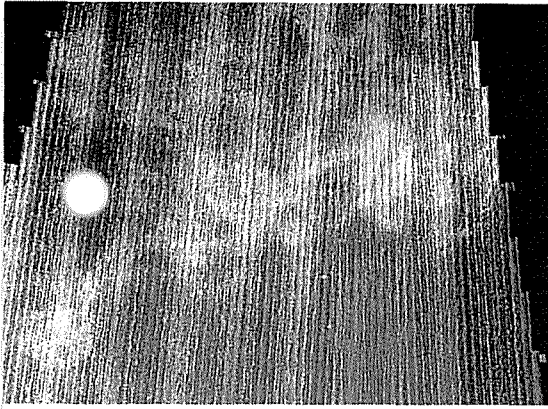
collisions must be extremely rare. The stars are far apart, and the chances of a star coming near the solar system in the Sun's lifetime are negligible. (And we would certainly see it coming.) We need not fear being hit by a star.

Star explosion

Another favourite science fiction disaster is the explosion of a star – a supernova. Although the Sun is a star, it is too small to become a supernova, so we need have no fear of the Sun blowing up. Only the largest and brightest stars, the supergiants, can explode as supernovae. A nearby supernova would be disastrous, but supergiants are very rare and there are none in our neighbourhood. In the last thousand years we know of only

Royal Observatory, Edinburgh





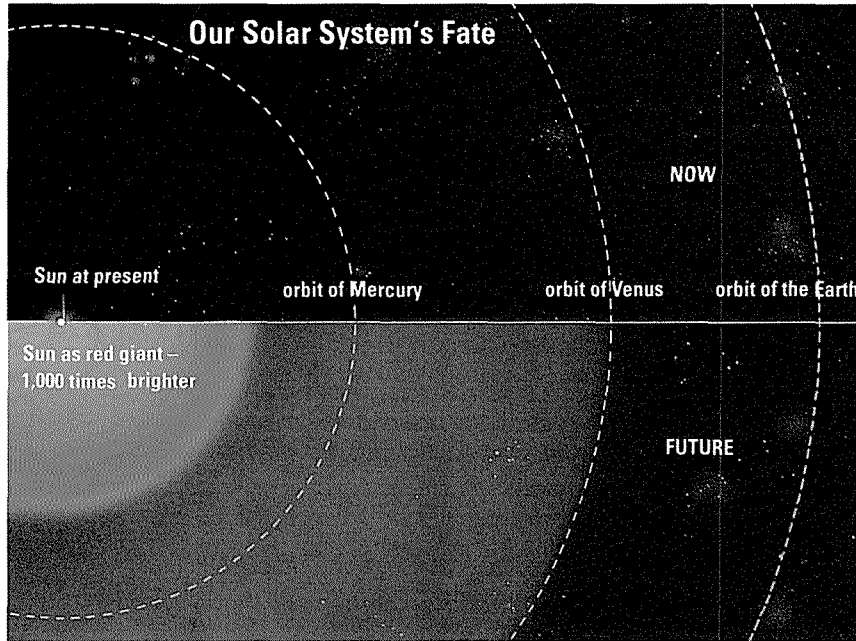
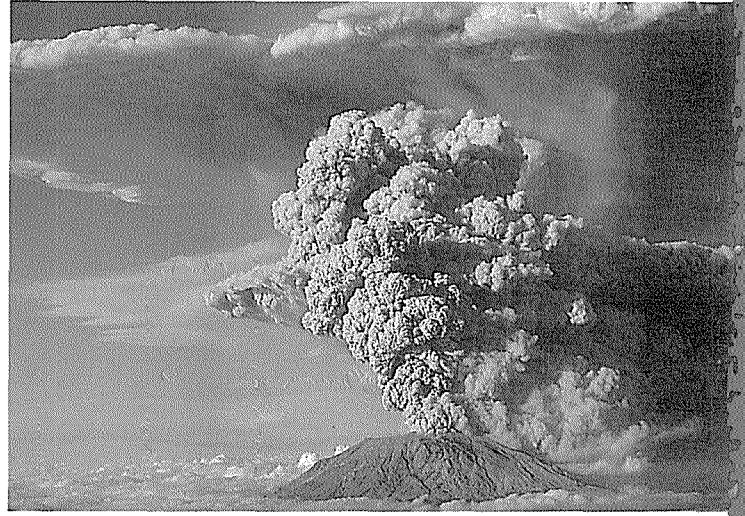
NASA/SPL six supernovae in our Galaxy, though only three are recorded in history and there must have been many others hidden from view by the obscuring dust clouds of interstellar space.

Could the dust clouds themselves be a threat? The Sun is moving in a circular path around the centre of the Galaxy, taking about 200 million years to make one circuit. What

would happen if it passed through one of the giant dust clouds? Sir Fred Hoyle, the famous astronomer, once wrote a story in which the solar system is plunged into a black cloud, blotting out the Sun and wreaking

Dust clouds in Space could influence our Earth's climate by obscuring the Sun. Now, even thin wispy clouds can be recorded on infrared pictures.

Massive volcanic eruptions like the one which occurred on Mount St Helens, USA, not only alter the landscape, they also account for sudden changes in the Earth's climate.



Paul Williams

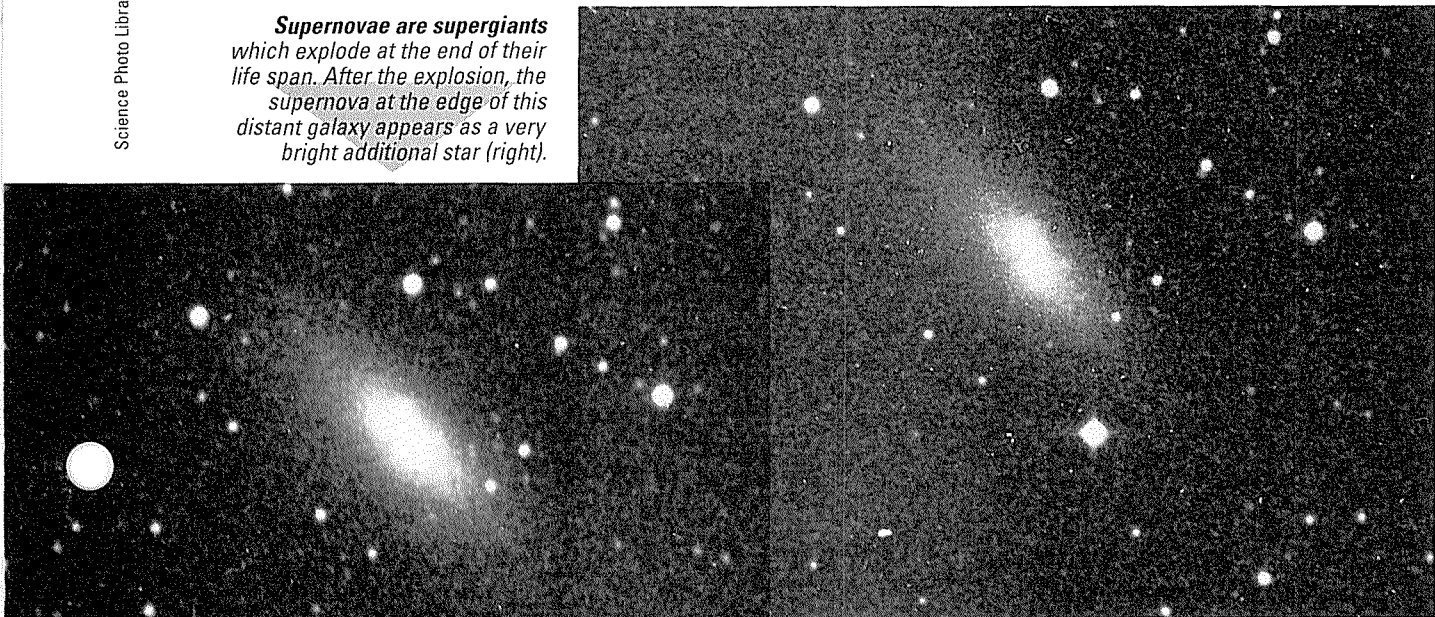
that a giant black hole resides at the very heart of the Galaxy. In certain other galaxies we see tremendous bursts of radiation from their centres. Could 'our' black hole suddenly erupt and send bursts of radiation through the Galaxy? Again, there is no evidence that this has happened in the life of the Earth.

Steady Sun

Suppose we do survive being hit by comets, asteroids and stars, smothered by clouds or blasted by a black hole. What happens then? Provided we don't destroy ourselves and our planet, there is no astronomical reason why we should not survive as

The Sun's lifecycle is far from complete - but at some stage in the very distant future, it will become a red giant, its scorching heat swallowing the planets closest to it.

Supernovae are supergiants which explode at the end of their life span. After the explosion, the supernova at the edge of this distant galaxy appears as a very bright additional star (right).

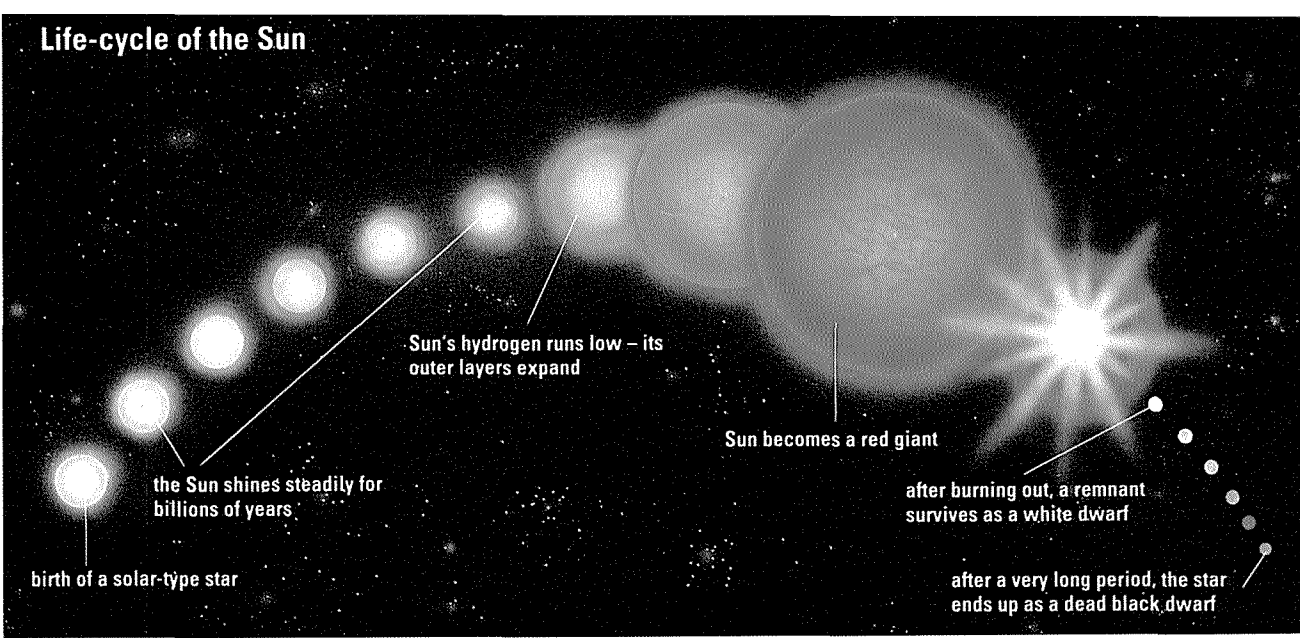


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Life-cycle of the Sun

Paul Williams



Royal Greenwich Observatory/SPL

Without the Sun, life on Earth would be impossible. Like any other star in the Universe, the Sun will eventually undergo a complete transformation – but not in the next five billion years!

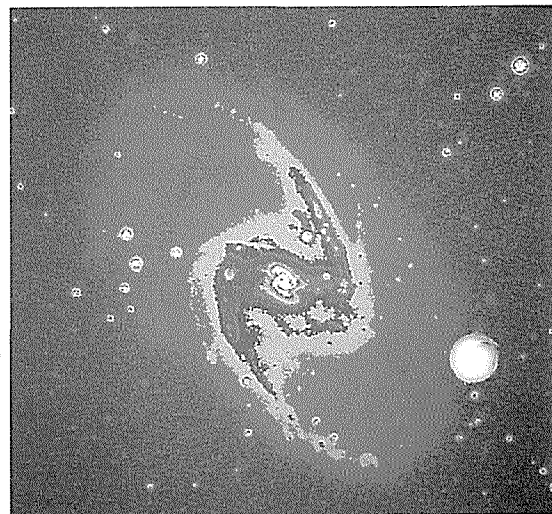
cally for at least four billion years.

We now know enough about the Sun to be confident that it will remain stable, even warming slightly, for perhaps another five billion years. But then the outlook is grim. One day it



Key Scott Design

An active galaxy depicted on a false colour photograph. Its unusually large output of X-rays might be due to a massive central black hole, tearing stars apart by tidal forces. It is possible that this could happen in our own Galaxy.



If the greenhouse effect was ever going to dominate the Earth's climate, our planet might rapidly become a hot and lifeless desert, with conditions similar to those on Venus, where temperatures can reach 500°C.

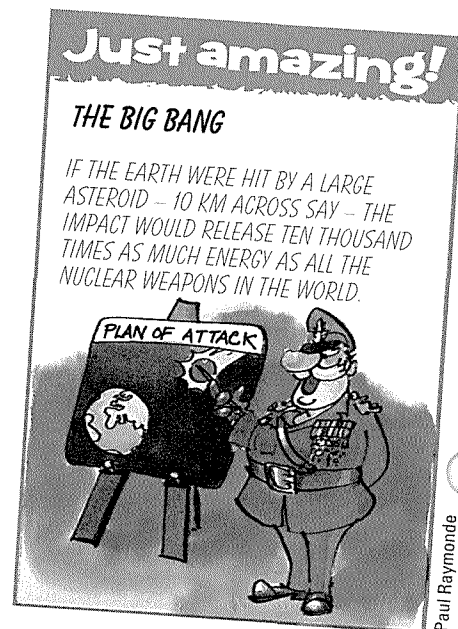
dying as a small, cold ember called a black dwarf.

So we need not worry about disaster coming from the sky. For the foreseeable future our destiny is very much in our own hands.

long as the Sun continues to shine.

All life on Earth depends on the Sun, and depends on it shining steadily. If the Sun were to become brighter or dimmer, conditions on Earth could change so much as to make it uninhabitable. If the Sun were to become much hotter the oceans would boil. If it became much cooler they would freeze. The fact that life evolved at all, however, shows that the output from the Sun has not changed catastrophically.

will run out of hydrogen fuel, and then our days will be numbered. The core of the Sun will shrink, but the outer layers will balloon out into a vast bloated star called a red giant. The inner planets, Mercury and Venus, will quickly cease to exist, but the Earth may briefly survive only to be melted and vaporized by the searing heat. And that will be the end of the Earth. The Sun will live on in a long series of exciting adventures before finally



Paul Raymond